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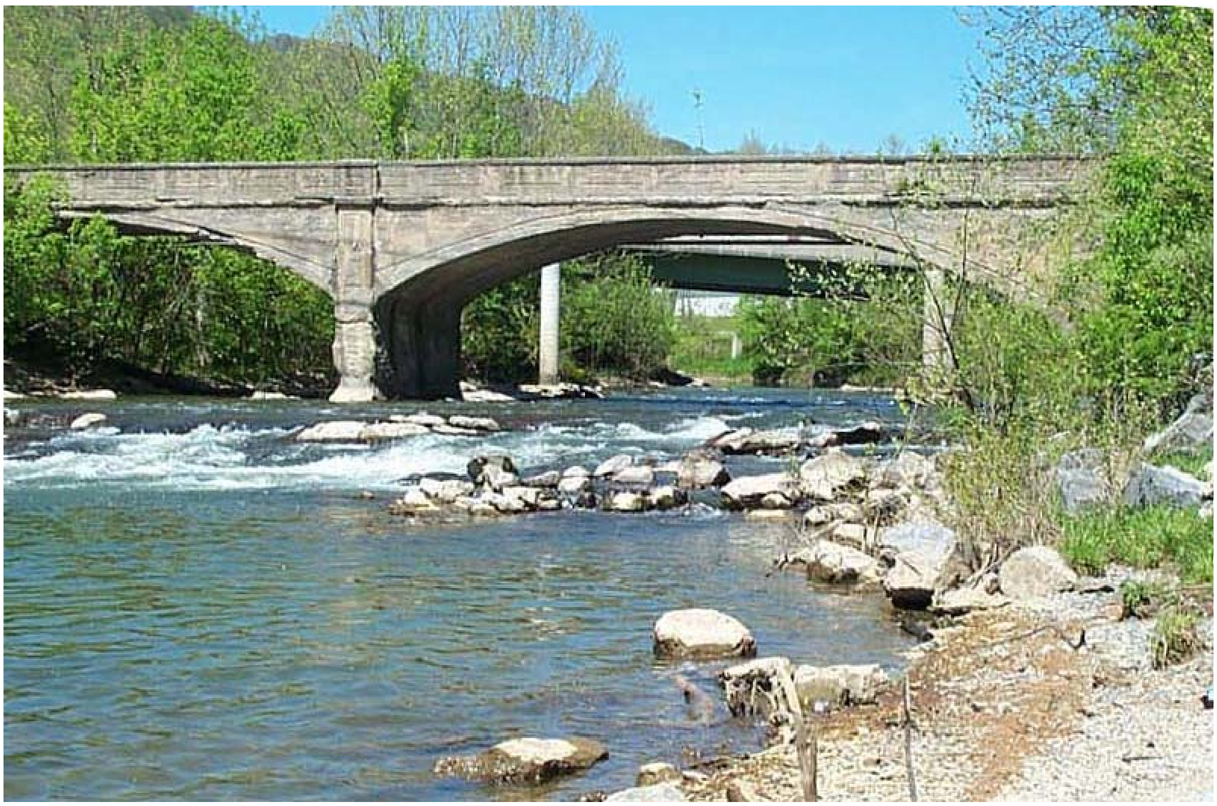
General Standard (Benthic) Total Maximum Daily Load Development for Upper North Fork Holston River



Prepared for
Virginia Department of Environmental Quality
January 5, 2006

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ACKNOWLEDGEMENTS

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VADEQ, Southwest Regional Office

Virginia Department of Conservation and Recreation (VADCR)

Virginia Department of Transportation - Bristol District (VDOT)

MapTech, Inc. of Blacksburg, Virginia, supported this study as a subcontractor to
New River-Highlands RC&D, through funding provided by
Virginia Department of Environmental Quality contract #99

EXECUTIVE SUMMARY

Background and Applicable Standards

The North Fork Holston River (watershed ID # VAS-O11R) was initially listed as impaired in 1996 (VADEQ, 1997). It appeared on the 1998 *303(d) TMDL Priority List and Report* (VADEQ & VADCR, 1998) for violations of the General Standard (benthic). The segment length for the aquatic life (benthic impairment) was listed as 6.94 stream miles. For the purposes of this report, this segment will be referred to as the Upper North Fork Holston River.

This segment remained on the *2002 303(d) Report on Impaired Waters* (VADEQ, 2002), but the stream length was decreased to 4.79 miles due to the National Hydrography Dataset (NHD) data layer. It was also placed on the *2004 305(b)/303(d) Water Quality Assessment Integrated Report* (VADEQ, 2004) for benthic impairments. The partially supporting aquatic life use designation is the result of a biological monitoring station (6CNFH080.45) rated moderately impaired in Fall 1993.

The General Standard is implemented by the Virginia Department of Environmental Quality (VADEQ) through application of the modified Rapid Bioassessment Protocol II (RBP II). Using the modified RBP II, the health of the benthic macroinvertebrate community is typically assessed through measurement of eight biometrics that evaluate the overall health community. Each biometric measured at a target station is compared to the same biometric measured at a reference (non-impaired) station to determine each biometric score. These scores are then summed and used to determine the overall bioassessment (*e.g.*, non-impaired, slightly impaired, moderately impaired, or severely impaired). Using this methodology, the Upper North Fork Holston River was rated as moderately impaired.

TMDL Endpoint and Water Quality Assessment

A Total Maximum Daily Load (TMDL) must be developed for a specific pollutant. Benthic assessments are very good at determining if a particular stream segment is impaired or not, but generally do not provide enough information to determine the cause(s) of the impairment. The process outlined in the Stressor Identification Guidance Document (EPA, 2000b) was used to identify stressors affecting the Upper North Fork Holston River. Chemical and physical monitoring data from VADEQ monitoring stations provided evidence to support or eliminate potential stressors. The potential stressors are: sediment, toxics, low dissolved oxygen, nutrients, pH, metals, conductivity/total dissolved solids, temperature, and organic matter.

The results of the stressor analysis for the Upper North Fork Holston River are divided into three categories:

> **Non-Stressor(s)**: Those stressors with data indicating normal conditions, without water quality standard violations, or without the observable impacts usually associated with a specific stressor, were eliminated as possible stressors.
>
> **Possible Stressor(s)**: Those stressors with data indicating possible links, but inconclusive data, were considered to be possible stressors.
>
> **Most Probable Stressor(s)**: The stressor(s) with the most consistent information linking it with the poorer benthic and habitat metrics was considered to be the most probable stressor(s).

The results indicate that total chloride is the Most Probable Stressor for the Upper North Fork Holston River and was used to develop the benthic TMDL.

Chloride is delivered to the Upper North Fork Holston River from a large culvert running through the town of Saltville. A salt pond in the town overflows into the culvert. The salt in the pond comes from a salt-water spring. Salt deposits are natural in the Saltville area. Chloride can also be delivered to the stream through surface runoff from roads that have had salt applied to them for snow and ice removal. Chloride concentrations are highest in the river during times of low flow when the flow from the culvert comprises a greater portion of the total stream flow. During winters with more frozen precipitation, more chloride is expected to be delivered to the stream due to increased application rates on the highways.

Modeling Procedures

Hydrology

The U.S. Geological Survey (USGS) Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to model hydrology and chloride loads. For purposes of modeling watershed inputs to in-stream water quality, the Upper North Fork Holston River drainage area was divided into 20 subwatersheds. The time period used for hydrologic calibration was 10/1/1995 through 9/30/2000. For hydrologic validation, the period selected was 10/1/1991 through 9/30/1995. Flow data was obtained from USGS # 03488000 located at Saltville, Virginia.

General Standard (benthic) - Chloride

The existing chronic water quality standard of 230 mg/L (four-day average not to be exceeded more than once every three years) was used to define allowable TMDL chloride loading rates in the Upper North Fork Holston River watershed. The HSPF water quality model was selected as the modeling framework to simulate conditions existing at the time of impairment and to perform TMDL allocations. The HSPF model is a continuous simulation model that can account for nonpoint source (NPS) pollutants in runoff, as well as pollutants entering the flow channel from point sources. In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities can be explicitly accounted for in the model. The use of HSPF allowed for consideration of seasonal aspects of precipitation patterns within the watershed.

Existing Conditions

The chloride TMDL for the Upper North Fork Holston River watershed was defined by the average annual chloride load in metric tons per year (kg/yr) where the VADEQ chronic water quality standard was not exceeded. The chloride load for existing conditions was calculated using the period of 10/1/1995 through 9/30/2000.

The chloride TMDL is composed of three components: waste load allocations (WLA) from point sources, the load allocation (LA) from nonpoint sources, and a margin of safety (MOS). The MOS was implicit for this study. The target chloride TMDL load for the Upper North Fork Holston River is 11,010,200 kg/yr. The existing load for the Upper North Fork Holston River is 37,938,000 kg/yr.

Load Allocation Scenarios

The next step in the chloride TMDL process was to reduce the various source loads to simulate an average annual chloride load that is no more than the target chloride TMDL load. Scenarios were evaluated to predict the effects of different combinations of source reductions on final in-stream water quality. Allocations were developed at the outlet of subwatershed 20.

The final load allocation scenario for the Upper North Fork Holston River required a 73.3% reduction in chloride loads from interflow and groundwater as well as a 100% reduction from failing septic systems, sewer system overflows and straight pipes (uncontrolled residential discharges) to the stream. No reductions to chloride permitted sources were required.

Table ES.1 Allocated chloride TMDL contributions from land-based (LA) and point sources (WLA) in the Upper North Fork Holston River.

Impairment	WLA (kg/year)	LA (kg/year)	MOS	TMDL (kg/year)
Upper North Fork Holston River	380,738	10,629,462	*Implicit*	11,010,200
VAG400080	*35*			
VA0026808	*44,679*			
VAG400145	*35*			
VA0090115	*335,989*			

Implementation

Implementation of Best Management Practices (BMPs) in the watershed will occur in stages. The Commonwealth of Virginia intends for the required BMPs to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. Specific goals for BMP implementation will be established as part of the implementation plan (IP) development and watershed stakeholders will have the opportunity to participate in the development of the TMDL IP.

It is anticipated that management of the salt ponds by the town of Saltville will be the initial target of implementation. The town of Saltville periodically adjusts the water level in the pond by reducing or increasing the overflow from the pond to the culvert. It is critical that the overflow should be carefully controlled when it is necessary to decrease the volume of the pond. Water should be released at a very slow rate over a period of days, especially during times of low flow in the Upper North Fork Holston River.

There is a measure of uncertainty associated with the final allocation development process. Monitoring performed upon completion of specific implementation milestones can provide insight into the effectiveness of implementation strategies, the need for amending the plan, and/or progress toward the eventual removal of the impairment from the 303(d) list.

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Once developed, VADEQ will take TMDL IPs to the State Water Control Board (SWCB) for approval as the plan for implementing the pollutant allocations and reductions contained in the TMDLs. Also, VADEQ will request SWCB authorization to incorporate the TMDL IP into the appropriate watershed plan. A guidance document outlining information included in Implementation Plans can be found at http://www.deq.state.va.us/tmdl/implans/ipguide.pdf. With successful completion of implementation plans, Virginia will be well on the way to restoring impaired waters and enhancing the value of this important resource.

Public Participation

During development of the TMDL for the Upper North Fork Holston River, public involvement was encouraged through two public meetings in the watershed. An introduction of the agencies involved, an overview of the TMDL process, and the specific approach to developing the Upper North Fork Holston River TMDL were presented at the first of the public meetings. Details of the pollutant sources and stressor identification were also presented at this meeting. Public understanding of, and involvement in, the TMDL process was encouraged. Input from this meeting was utilized in the development of the TMDL and improved confidence in the allocation scenarios.

The final model simulations and the TMDL load allocations were presented during the final public meeting. There was a 30-day public comment period after the final public meeting and X written comments were received. Watershed stakeholders will have the opportunity to participate in the development of the TMDL IP.

1. INTRODUCTION

1.1 Background

The need for a Total Maximum Daily Load (TMDL) for the Upper North Fork Holston watershed was based on provisions of the federal Clean Water Act (CWA). The United States Environmental Protection Agency's (EPA) document, *Guidance for Water Quality-Based Decisions: The TMDL Process* (EPA, 1999), states:

> *According to Section 303(d) of the Clean Water Act and the USEPA water quality planning and management regulations, States are required to identify waters that do not meet or are not expected to meet water quality standards even after technology-based or other required controls are in place. The waterbodies are considered water quality-limited and require TMDLs.*
>
> *…A TMDL is a tool for implementing State water quality standards, and is based on the relationship between pollution sources and in-stream water quality conditions. The TMDL establishes the allowable loadings or other quantifiable parameters for a waterbody and thereby provides the basis for States to establish water quality-based controls. These controls should provide the pollution reduction necessary for a waterbody to meet water quality standards.*

The North Fork Holston watershed (within USGS Hydrologic Unit Code #06010101) is located within Virginia's Tazewell, Bland, Scott, Smyth and Washington Counties (Figure 1.1). The partially supporting segment is the mainstem of the North Fork Holston River, from Robertson Branch in Saltville to Tumbling Creek. The North Fork Holston River is part of the Tennessee/Big Sandy River Drainage Basin, and drains via the Mississippi River to the Gulf of Mexico. The drainage area to the impaired segment of the North Fork Holston River is approximately 165,490 acres (Figure 1.2). For the purposes of this report, this segment will be referred to as the Upper North Fork Holston River.

The North Fork Holston River (watershed ID # VAS-O11R) was initially listed as impaired in 1996 (VADEQ, 1997). It appeared on the 1998 *303(d) TMDL Priority List* and Report (VADEQ & VADCR, 1998) for violations of the General Standard and the watershed was ranked high priority for potential nonpoint source (NPS) pollution by the Virginia Department of Conservation and Recreation (VADCR). The segment length for the aquatic life (benthic) impairment was listed as 6.94 stream miles.

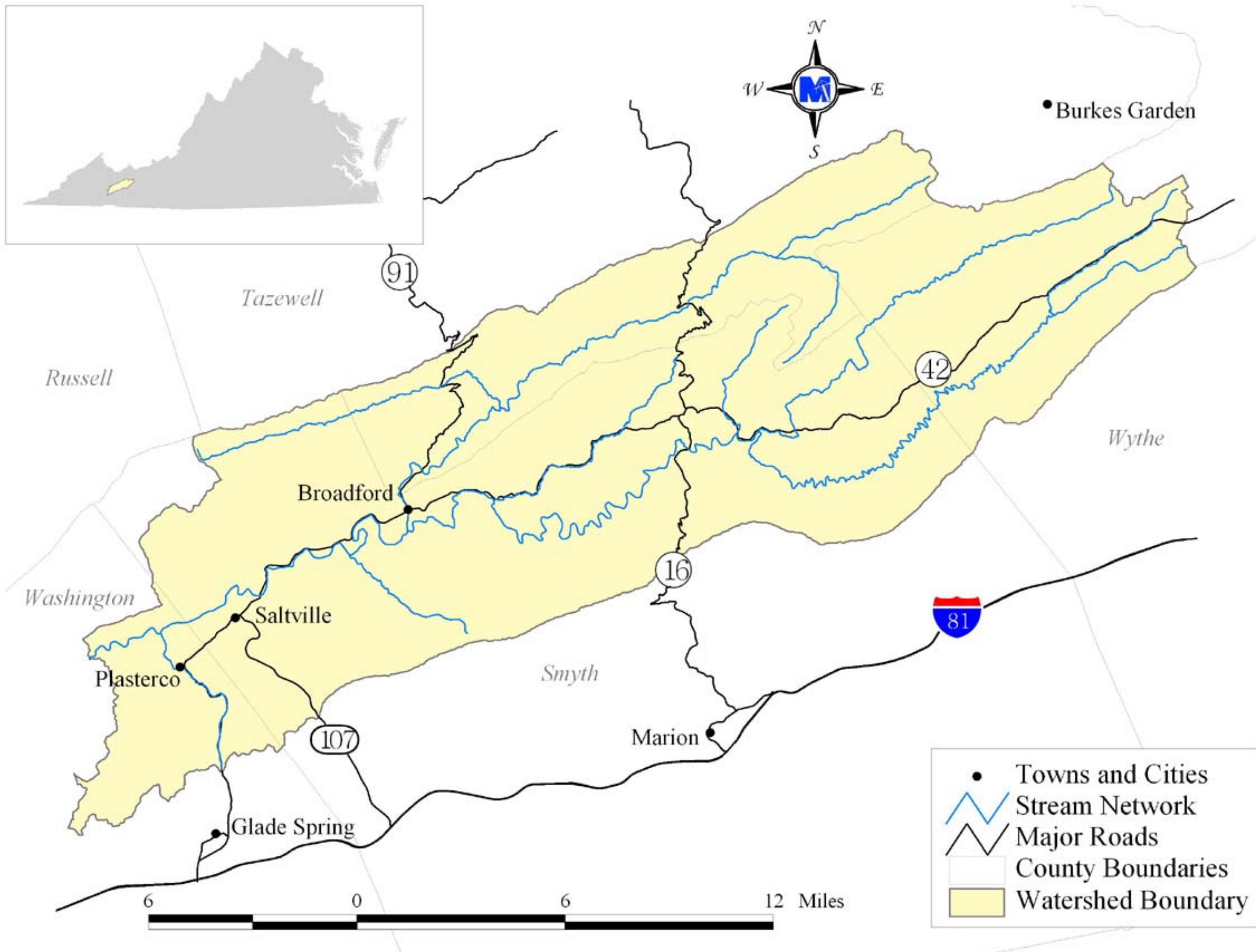

Figure 1.1 Location of the North Fork Holston River watershed.

In the *2002 303(d) Report on Impaired Waters* (VADEQ, 2002), the North Fork Holston River was listed for violations of the General Standard (benthic). The stream length for this segment was decreased to 4.79 miles due to refinement using the National Hydrography Dataset (NHD) data layer. No benthic data fell within the 2002 assessment window; therefore, the North Fork Holston River is not listed as impaired for benthics in the 2002 305(b) report.

The North Fork Holston River remained on the *2004 Virginia Water Quality Assessment 305(b)/303(d) Integrated Report* (VADEQ, 2004) for benthic impairments. The partially supporting aquatic life use designation is the result of a biological monitoring station (6CNFH080.45) rated moderately impaired that was last sampled in 1993.

While the 2002 report cites VDH Health Advisory (Mercury) and the 2004 report cites VDH Health Advisory (Mercury, PCB), this TMDL will deal only with the benthic impairment in the North Fork Holston River.

2. WATER QUALITY ASSESSMENT

2.1 Applicable Water Quality Standards

Virginia state law 9VAC25-260-10 (Designation of uses) indicates:

A. All state waters, including wetlands, are designated for the following uses: recreational uses, e.g., swimming and boating; the propagation and growth of a balanced, indigenous population of aquatic life, including game fish, which might reasonably be expected to inhabit them; wildlife; and the production of edible and marketable natural resources, e.g., fish and shellfish.

♦

D. At a minimum, uses are deemed attainable if they can be achieved by the imposition of effluent limits required under §§301(b) and 306 of the Clean Water Act and cost-effective and reasonable best management practices for nonpoint source control.

♦

G. The [State Water Control] board may remove a designated use which is not an existing use, or establish subcategories of a use, if the board can demonstrate that attaining the designated use is not feasible because:

1. *Naturally occurring pollutant concentrations prevent the attainment of the use;*
2. *Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation requirements to enable uses to be met;*

♦

6. *Controls more stringent than those required by §§301(b) and 306 of the Clean Water Act would result in substantial and widespread economic and social impact.*

2.2 Applicable Criterion for Benthic Impairment

Additionally, Virginia state law 9VAC25-260-20 defines the **General Standard** as:

A. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life.

2.3 Benthic Assessment

The General Standard is implemented by the Virginia Department of Environmental Quality (VADEQ) through application of the modified Rapid Bioassessment Protocol II (RBP II).

Using the modified RBP II, the health of the benthic macroinvertebrate community is typically assessed through measurement of eight biometrics which measure different aspects of the community's overall health (Table 2.1). Surveys of the benthic macroinvertebrate community performed by VADEQ are assessed at the family taxonomic level. A score within the non-impaired range is the endpoint for General Standard (benthic) impaired TMDLs.

Table 2.1 Components of the RBP II Assessment.

Biometric	Benthic Health [1]
Taxa Richness	↑
Modified Family Biotic Index (MFBI)	↓
Scraper to Filtering Collector Ratio	↑
EPT / Chironomid Ratio	↑
% Contribution of Dominant Family	↓
EPT Index	↑
Community Loss Index	↓
Shredder to Total Ratio	↑

[1] An upward arrow indicates a positive response in benthic health when the associated biometric increases.

Each biometric measured at a target station is compared to the same biometric measured at a reference (non-impaired) station to determine each biometric score. These scores are then summed and used to determine the overall bioassessment (*e.g.*, not impaired, slightly impaired, moderately impaired, or severely impaired).

RBP II benthic surveys were performed by the VADEQ in October 1992, November 1993, June 2003, and November 2003 at benthic monitoring station 6CNFH080.45 on the Upper North Fork Holston River. The Fall 1992 result indicated a moderate impairment and the stream was placed on Virginia's 303(d) list for not attaining the aquatic life use. The results of the RBP II benthic monitoring surveys at station 6CNFH080.45 are presented in Table 2.2. The table indicates that surveys in Fall 1992 and Fall 1993 found a moderately impaired condition.

An alternative method to the modified RBP II is the Virginia Stream Condition Index (VASCI). The VASCI is being developed, and data is being collected to calibrate and further validate the VASCI method. Eight biometrics are obtained, with higher scores indicating a healthier benthic community. The advantage of the VASCI is that the score does not depend upon values from a reference station. The VASCI has an impairment threshold of 61.3 and the scores for the VADEQ surveys are presented in Table 2.3. Figure 2.1 is a graphical representation of the VASCI scores for VADEQ monitoring stations 6CNFH080.45, and upstream reference stations 6CNFH085.31 and 6CNFH098.47. Note that the scores for all four surveys at VADEQ station 6CNFH080.45 were below the impairment threshold of 61.3.

Table 2.2 RBP II biological monitoring data for station 6CNFH080.45 on the Upper North Fork Holston River.

Date	Assessment	Reference Station
10/14/1992	Moderately Impaired	6CNFH098.47
11/4/1993	Moderately Impaired	6CNFH098.47
6/25/2003	Slightly Impaired	6CNFH085.31
11/5/2003	Slightly Impaired	6CNFH085.31

Table 2.3 VASCI data for the VADEQ benthic surveys at station 6CNFH080.45 and upstream reference stations on the Upper North Fork Holston River.

Station	**6CNFH098.47**	**6CNFH080.45**	**6CNFH098.47**	**6CNFH080.45**	**6CNFH085.31**	**6CNFH080.45**	**6CNFH085.31**	**6CNFH080.45**
Metric	**10/92**	**10/92**	**11/93**	**11/93**	**06/03**	**06/03**	**11/03**	**11/03**
Richness Score	68.2	36.4	59.1	50.0	81.8	54.5	63.6	54.5
EPT Score	72.7	27.3	63.6	45.5	90.9	45.5	72.7	54.5
% Ephem. Score	26.7	0.0	31.5	5.3	58.9	16.3	62.4	9.0
% PT-H* Score	11.9	9.4	17.2	27.2	11.6	0.0	14.7	6.2
% Scraper Score	100.0	93.2	100.0	100.0	58.2	100.0	77.1	74.4
% Chironomidae Score	98.8	94.4	97.4	95.2	89.7	96.4	98.3	91.2
%2 Dominant Score	43.7	68.9	49.4	45.4	93.7	38.0	70.3	31.7
% MFBI Score	88.9	74.3	90.0	86.3	89.0	86.0	90.2	76.6
VASCI Score	**63.9**	**50.5**	**63.5**	**56.8**	**71.7**	**54.6**	**68.7**	**49.8**

* Hydropsychidae (netspinning caddisflies)

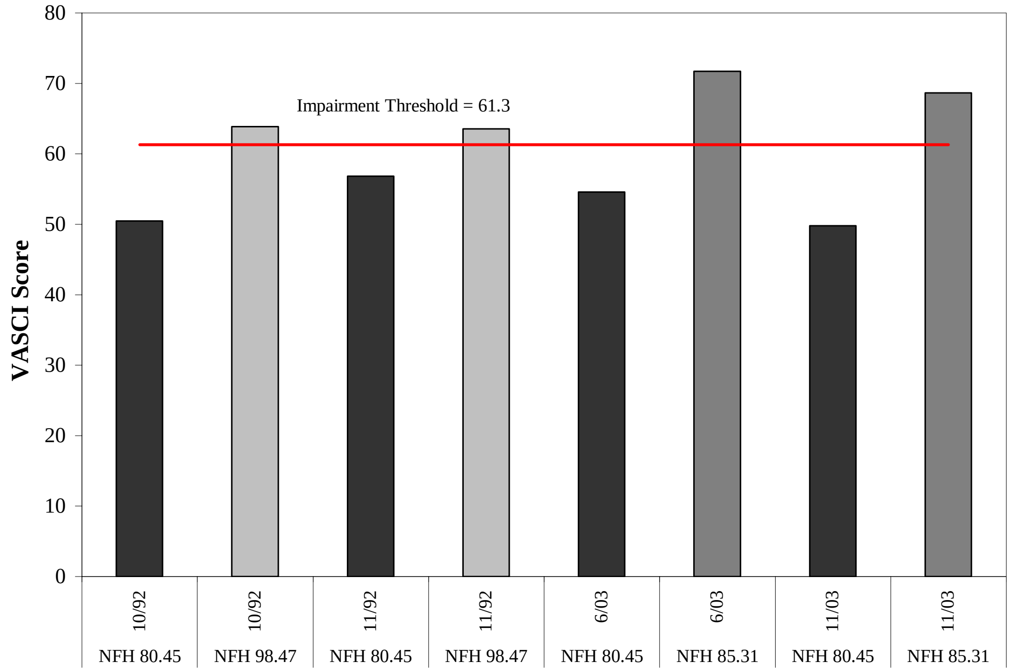

Figure 2.1 VASCI scores at VADEQ benthic monitoring station 6CNFH080.45 and upstream reference stations.

2.4 Habitat Assessment

Benthic impairments have two general causes: input of pollutants to streams, and alteration of habitat in either the stream or the watershed. Habitat can be altered directly (*e.g.*, by channel modification), indirectly (because of changes in the riparian corridor leading to conditions such as streambank destabilization), or even more indirectly (*e.g.*, due to land use changes in the watershed such as clearing large areas).

Habitat assessments are normally carried out as part of the benthic sampling. The overall habitat score is the sum of 10 individual metrics, each metric ranging from 0 to 20. The classification schemes for both the individual habitat metrics and the overall habitat score for a sampling site are shown in Table 2.4.

Table 2.4 Classification of habitat metrics based on score.

Habitat Metric	Optimal	Sub-optimal	Marginal	Poor
Embeddedness	16 – 20	11 – 15	6 - 10	0 - 5
Epifaunal Substrate	16 – 20	11 – 15	6 - 10	0 - 5
Pool Sediment	16 – 20	11 – 15	6 - 10	0 - 5
Flow	16 – 20	11 – 15	6 - 10	0 - 5
Channel Alteration	16 – 20	11 – 15	6 - 10	0 - 5
Riffles	16 – 20	11 – 15	6 - 10	0 - 5
Velocity	16 – 20	11 – 15	6 - 10	0 - 5
Bank Stability	18 – 20	12 – 16	6 - 10	0 - 4
Bank Vegetation	18 – 20	12 – 16	6 - 10	0 - 4
Riparian Vegetation	18 – 20	12 – 16	6 - 10	0 - 4
Overall Score	**166 - 200**	**113 - 153**	**60 -100**	**0 - 47**

Habitat assessment for the Upper North Fork Holston River will include an analysis of habitat scores recorded by the VADEQ biologist. The VADEQ habitat assessments on the Upper North Fork Holston River for the 2003 benthic surveys are displayed in Table 2.5. The riffle metric scores are in the marginal category for both surveys. This metric is a measure of the frequency of riffles in the sampling area of the stream. Riffle areas are the most important habitat in high gradient streams. A marginal score indicates a high percentage of flat water. Embeddedness is a measure of the extent to which the suitable riffle habitat is covered or sunken into sediment. Marginal Embeddedness scores indicate a significant loss of habitat due to sediment deposition. The Upper North Fork of the Holston River had a marginal rating for Embeddedness in the Fall 2003. Pool Sediment is a metric that measures the amount of sediment deposition in the pool areas of the stream. The Upper North Fork Holston River had marginal scores for this metric in both of the 2003 benthic surveys. This indicates that 30 to 50% of the pool bottom is affected by sediment.

Table 2.5 Habitat scores for VADEQ monitoring station 6CNFH080.45 on the Upper North Fork Holston River.

Metric	Jun-03	Nov-03
Channel Alteration	18	18
Bank Stability	16	14
Bank Vegetation	18	16
Embeddedness	11	6
Flow	18	14
Riffles	9	7
Riparian Vegetation	18	17
Pool Sediment	7	7
Epifaunal Substrate	16	14
Velocity	16	14
TOTAL	**147**	**127**

2.5 Discussion of In-stream Water Quality

This section provides an inventory of available observed in-stream monitoring data throughout the Upper North Fork Holston River watershed. An examination of data from water quality stations used in the Section 305(b) assessment and data collected during TMDL development were analyzed. Sources of data and pertinent results are discussed.

2.5.1 Inventory of Water Quality Monitoring Data

The primary source of available water quality information for the Upper North Fork Holston River is data collected at 14 monitoring stations in the upper section of the stream where the impairment is located (Figure 2.2 and Table 2.6). The data is summarized in Tables 2.7 through 2.26.

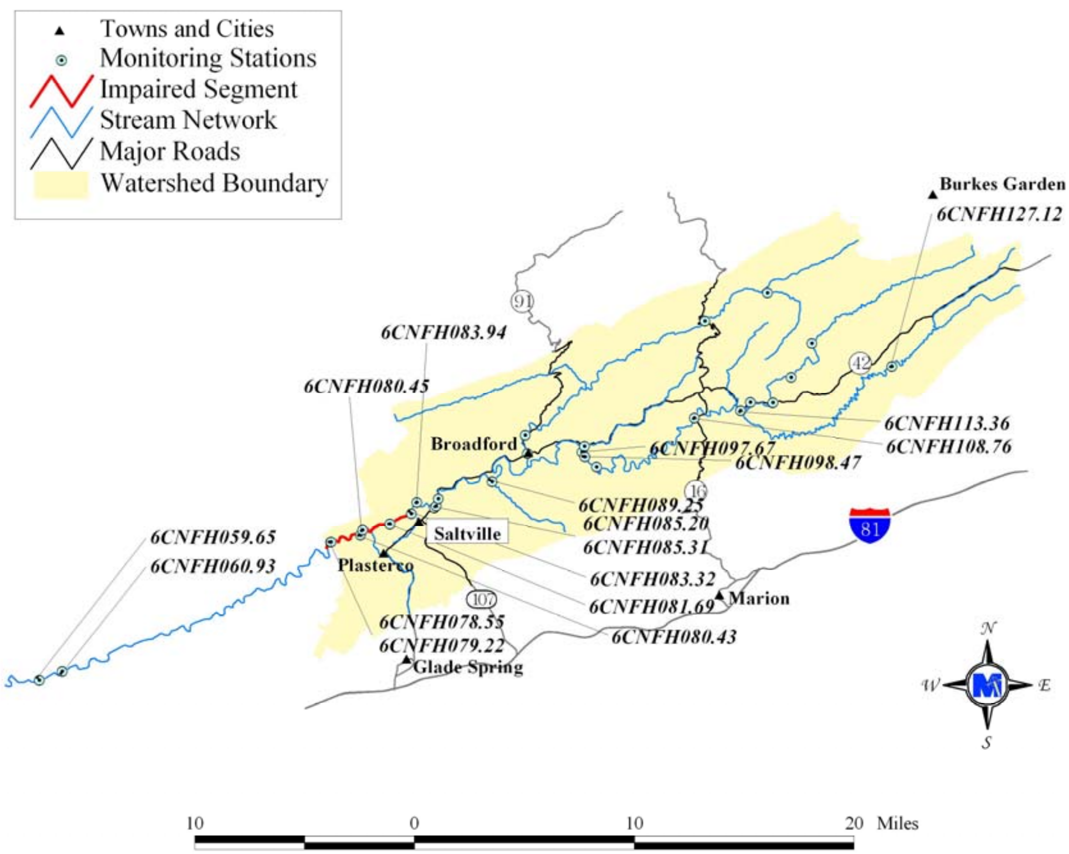

Figure 2.2 Location of VADEQ in-stream water quality monitoring stations in the upper section of the North Fork Holston River.

Table 2.6 VADEQ monitoring stations in the upper section of the North Fork Holston River*.

Station	Type	Data Record
6CNFH059.65	Ambient	1/1990 – 3/2001
6CNFH060.93	Biological	5/2002
6CNFH079.22	Ambient	7/2003 – 6/2004
6CNFH080.43	Ambient	1/1990 – 6/2004
6CNFH081.69	Ambient	7/2003 – 6/2004
6CNFH083.32	Ambient	1/1990 – 9/1991
6CNFH083.94	Probabilistic	5/2002
6CNFH085.20	Ambient	1/1990 – 3/2005
6CNFH089.25	Ambient	5/1992 – 3/2001
6CNFH097.67	Ambient	1/1990 – 10/1991
6CNFH098.47	Ambient/Biological	4/1995 – 9/2002
6CNFH108.76	Probabilistic	5/2002
6CNFH113.36	Ambient	8/2001 – 6/2003
6CNFH127.12	Ambient	8/2001 – 6/2003

* Special study stations will be reviewed separately.

Table 2.7 In-stream water quality data at 6CNFH059.65 (1/90-3/01).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Alkalinity (mg/L)	93.72	92.7	205	39.4	24.26	119
BOD5 (mg/L)	1.31	1	3	1	0.61	46
Chloride, Total (mg/L)	88.69	77.4	272	4.4	63.52	120
COD (mg/L)	8.95	7.1	46	2.4	6.26	82
Conductivity (µmhos/cm)	479.99	422	1,170	115.5	249.97	121
Dissolved Oxygen (DO) (mg/L)	9.73	9.22	15.5	5.19	2.38	99
Field pH (std units)	7.89	7.88	8.8	6.73	0.34	118
Fluoride, Total (mg/L)	0.23	0.11	0.87	0.07	0.27	10
NH3+NH4-N TOTAL (mg/L)	0.05	0.05	0.07	0.04	0.01	11
Nitrate, Total (mg/L as N)	0.47	0.44	1.05	0.07	0.23	115
Nitrite, Total (mg/L as N)	0.06	0.01	1	0.01	0.21	22
Nitrogen, Total Kjeldahl (TKN)(mg/L as N)	0.32	0.3	1.2	0.1	0.21	111
Orthophosphorus, Dissolved (mg/L as P)	0.02	0.01	0.04	0.01	0.01	10
Orthophosphorus, Total (mg/L as P)	0.02	0.02	0.09	0.01	0.01	67
Phosphorus, Total (mg/L as P)	0.03	0.02	0.2	0.01	0.03	107
Solids, Total (mg/L)	317.51	273.5	752	76	155.89	120
Solids, Total dissolved (TDS) (mg/L)	286	255	655	69	142	120
Solids, Total inorganic (mg/L)	243.9	223.5	596	54	120.86	120
Solids, Total inorganic suspended, (mg/L)	14.51	5	284	1	37.05	69
Solids, Total suspended (TSS) (mg/L)	11.65	5	114	1	18.94	79
Solids, Total organic (mg/L)	73.86	61.5	216	15	46.09	118
Solids, Total organic suspended (mg/L)	3.3	2	20	1	3.94	40
Sulfate, Total (mg/L)	22.95	20	55.9	5.1	10.59	120
Temperature (Celsius)	14.08	15.2	27.3	0	7.79	119
Total Hardness CACO3 (mg/L)	150.26	136	300	2.3	56.14	123
Total Organic Carbon (TOC) (mg/L)	2.76	2.2	17.5	0.62	2.36	68
Turbidity Field NTU	7.3	2.4	113	0.78	22.09	25
Turbidity Hach Turbidimeter	6.15	3.45	61	0.57	9.66	76
Turbidity JTU	8.03	2.6	70	0.5	16.32	19
Water Column Metals						
Iron, Total (µg/L)	95.25	106.02	142.79	36.37	40.05	7
Magnesium, Total (mg/L)	11,208	10,785	16,710	5,710	4,183	6
Manganese, Total (µg/L)	18.91	14.96	31.74	10	9.56	6
Sediment Metals						
Aluminum in mud (mg/kg dry wt)	12,267	13,400	16,100	7,050	3,452	5
Antimony, Sediment (mg/kg dry wt)	9	9	13	5	5.66	2
Arsenic, Sediment (mg/kg dry wt)	5.62	5	7	5	0.91	5
Chromium, Sediment (mg/kg dry wt)	15.27	16	22	9	3.97	9
Copper, Sediment (mg/kg dry wt)	25.01	24	42	17	8.16	9
Iron in mud (mg/kg dry wt)	19,413	20,100	25,964	12,400	5,287	5
Lead, Sediment (mg/kg dry wt)	26.41	22.7	52	18	10.49	9
Manganese in mud (mg/kg dry wt)	598.4	615	817	420	155.16	5
Mercury, Sediment (mg/kg dry wt)	2.76	1.53	5.6	1.2	2.13	6

Table 2.7 In-stream water quality data at 6CNFH059.65 (1/90-3/01) (cont.).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Sediment Metals						
Nickel, Sediment (mg/kg dry wt)	17.86	20	22	11	4.16	9
Zinc, Sediment (mg/kg dry wt)	81	82.5	107	47	21.96	8

[1]SD: standard deviation, [2]N: number of sample measurements.

Table 2.8 Single sample in-stream water quality data at 6CNFH059.65 (8/2000).

Water Quality Constituent	Value
Water Column Metals	
Aluminum, Dissolved (µg/L)	13.4
Arsenic, Dissolved (µg/L)	0.90
Calcium, Dissolved (mg/L)	32.1
Calcium, Total (µg/L)	27,580
Copper, Dissolved (µg/L)	0.80
Copper, Total (µg/L)	20.0
Lead, Dissolved (µg/L)	0.10
Magnesium, Dissolved (mg/L)	5.7
Manganese, Dissolved (µg/L)	2.3
Nickel, Dissolved (µg/L)	0.60
Selenium, Total (µg/L)	26.5
Sediment Metals	
Beryllium, Sediment (mg/kg dry wt)	1.00
Cadmium in mud (mg/kg dry wt)	1.00
Thallium, Sediment (mg/kg dry wt)	16.0
Selenium, Sediment (mg/kg dry wt)	10.0
Sediment PCB	
PCBs, Total Sediment (µg/kg dry wt)	15.0

Table 2.9 In-stream water quality data at 6CNFH060.93 (5/2002).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Conductivity (µmhos/cm)	554	554	700	407	207	2
Dissolved Oxygen (DO) (mg/L)	9	9	10	7	2	2
Field_pH (std units)	8	8	8	7	0	2
Temperature (Celsius)	20	20	21	20	0	2

[1]SD: standard deviation, [2]N: number of sample measurements

Table 2.10 In-stream water quality data at 6CNFH079.22 (7/03-6/04).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Conductivity (µmhos/cm)	589	499	1,180	218	279	12
Dissolved Oxygen (DO) (mg/L)	11	11.32	14.05	7.74	2.33	12
Field pH (std units)	8.14	8.06	8.62	7.8	0.25	12
Nitrite + Nitrate (mg/L as N)	0.63	0.61	0.8	0.43	0.12	12
Nitrogen, Total (mg/L)	0.81	0.8	1.17	0.55	0.16	12
Phosphorus, Total (mg/L as P)	0.02	0.02	0.04	0.01	0.01	10
Solids, Total dissolved (mg/L)	332	300	670	123	156.11	12
Solids, Total suspended (TSS) (mg/L)	17.5	14	36	4	14.83	6
Temperature (Celsius)	12.54	12.7	21.4	0.06	6.93	12
Turbidity Lab NTU	7.78	2.65	28	1	9.4	12

[1]SD: standard deviation, [2]N: number of sample measurements.

Table 2.11 In-stream water quality data at 6CNFH080.43 (1/90-6/04).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Alkalinity (mg/L)	107.39	103	160	41.3	29.55	77
BOD5 (mg/L)	1.32	1	4	1	0.65	30
Chloride, Total (mg/L)	171.83	145	951	7.8	137.64	77
COD (mg/L)	8.54	6.7	22	1.5	5.17	43
Conductivity (µmho/cm)	747	680	1,980	109	408	90
Dissolved Oxygen (DO) (mg/L)	11.1	10.82	17.62	6.97	2.61	68
Field pH (std units)	8.23	8.17	9.23	7.42	0.4	88
Fluoride, Total (mg/L)	0.23	0.15	0.69	0.1	0.2	9
Mercury, Sediment (mg/kg dry wt)	3.2	2.42	7.36	1.88	1.73	9
NH3+NH4-N TOTAL (mg/L)	0.05	0.05	0.08	0.04	0.01	16
Nitrate, Total (mg/L as N)	0.61	0.56	1.08	0.22	0.2	75
Nitrite + Nitrate (mg/L as N)	0.62	0.62	0.78	0.42	0.12	12
Nitrite, Total (mg/L as N)	0.02	0.01	0.06	0.01	0.01	21
Nitrogen, Total (mg/L)	0.79	0.81	1.01	0.53	0.15	12
Nitrogen, Total Kjeldahl (TKN) (mg/L) as N)	0.44236	0.3	1.8	0.1	0.35	72
Orthophosphorus, Dissolved (mg/L as P)	0.02	0.02	0.05	0.01	0.01	14
Orthophosphorus, Total (mg/L as P)	0.02	0.02	0.11	0.01	0.02	38
Phosphorus, Total (mg/L as P)	0.04	0.02	0.43	0.01	0.05	75
Solids, Total (mg/L)	562.667	493	2,876	111	400.035	75
Solids, Total dissolved (TDS) (mg/L)	499	382	2,872	91	382	86
Solids, Total inorganic (mg/L)	433.32	375	2,236	94	307.65	76
Solids, Total inorganic suspended (mg/L)	16.91	5	216	1	40.78	35
Solids, Total suspended (TSS) (mg/L)	16.7059	6	247	1	39.0258	51
Solids, Total organic (mg/L)	128.066	106	640	17	95.2423	76
Solids, Total organic suspended (mg/L)	4.68	3	31	1	6.54	25
Sulfate, Total (mg/L)	34.83	28.3	145	10.5	22.46	77
Temperature (Celsius)	14.07	14.15	26.6	0	7.73	90
Total Hardness CACO3 (mg/L)	211.852	201	600	64	99.007	77
Total Organic Carbon (TOC) (mg/L)	2.14944	1.7	10.3	0.65	1.66	36
Turbidity Field NTU	27.8	2.05	260	0.81	81.6	10
Turbidity Hach Turbidimeter FTU	4.6	2.22	57	0.36	8.99	47
Turbidity JTU	5.19	2.9	21	1.1	5.19	19
Turbidity Lab NTU	6.98	3.3	23	1.1	7.55	12
Water Column Metals						
Iron, Total (µg/L)	110.2	89.81	179.95	42.93	57.67	5
Magnesium, Total (mg/L)	12,100	14,710	16,940	4,160	5,166	5
Manganese, Total (µg/L)	63.17	26.25	259.3	13.86	96.48	6

[1]SD: standard deviation, [2]N: number of sample measurements.

Table 2.11 In-stream water quality data at 6CNFH080.43 (1/90-6/04) (cont.).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Sediment Metals						
Aluminum in mud (mg/kg dry wt)	10,137	9,706	17,700	5,370	4,556	6
Antimony, Sediment (mg/kg dry wt)	7.33	8	8	6	1.15	3
Arsenic, Sediment (mg/kg dry wt)	6.9	6	12	4	2.58	7
Chromium, Sediment (mg/kg dry wt)	13.16	12	21	8	4.12	11
Copper, Sediment (mg/kg dry wt)	32.17	32	52	10.6	14.64	11
Iron in mud (mg/kg dry wt)	17,709	16,978	23,100	13,100	4,197	6
Lead, Sediment (mg/kg dry wt)	19.73	19	36	12	6.67	11
Manganese in mud (mg/kg dry wt)	888.67	742.5	1,520.00	455	402.19	6
Nickel, Sediment (mg/kg dry wt)	17.07	14	28	11	5.8	11
Selenium, Sediment (mg/kg dry wt)	9.5	9.5	11	8	2.122	2
Zinc, Sediment (mg/kg dry wt)	75.58	77	151	30	34.28	11

[1]SD: standard deviation, [2]N: number of sample measurements.

Table 2.12 Single sample in-stream water quality data at 6CNFH080.43 (7/2003).

Water Quality Constituent	Value
Water Column Metals	
Aluminum, Dissolved (µg/L)	2.44
Arsenic, Dissolved (µg/L)	0.44
Chromium, Dissolved (µg/L)	0.95
Copper, Dissolved (µg/L)	0.58
Copper, Total (µg/L)	20
Manganese, Dissolved (µg/L)	15.1
Magnesium, Dissolved (mg/L)	15
Nickel, Dissolved (µg/L)	0.63
Selenium, Total (µg/L)	25.04
Zinc, Total (µg/L)	57.38
Sediment Metals	
Cadmium in mud (mg/kg dry wt)	2

Table 2.13 In-stream water quality data at 6CNFH081.69 (7/03-6/04).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Conductivity (µmhos/cm)	580	539	1071	288	237	12
Dissolved Oxygen (DO) (mg/L)	10.44	10.46	14.14	8.04	1.95	12
Field_pH (std units)	8.02	7.99	8.32	7.48	0.23	12
Nitrite + Nitrate (mg/L as N)	0.6	0.63	0.74	0.42	0.11	12
Nitrogen, Total (mg/L)	0.8	0.82	0.97	0.53	0.15	12
Phosphorus, Total (mg/L as P)	0.02	0.02	0.03	0.01	0.01	11
Solids, Total dissolved (mg/L)	316	284	574	118	126	12
Solids, Total suspended (TSS) (mg/L)	10.57	6	29	3	9.03	7
Temperature (Celsius)	12.61	12.3	21.7	0.05	7.03	12
Turbidity Lab NTU	5.98	3	25	1.5	6.87	12

[1]SD: standard deviation, [2]N: number of sample measurements.

Table 2.14 In-stream water quality data at 6CNFH083.32 (1/90-9/91).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Alkalinity (mg/L)	103.19	92	161	60.4	30.36	20
BOD5 (mg/L)	1.06	1	2	1	0.24	17
Chloride, Total (mg/L)	3.74	3.2	7.43	1.9	1.64	19
COD (mg/L)	5.2	4.15	15	2	3.2	20
Conductivity (µmhos/cm)	234	206	360	150	59	20
Field pH (std units)	8.3	8.34	8.7	7.73	0.25	18
Fluoride, Total (mg/L)	0.09	0.1	0.11	0.05	0.02	5
NH3+NH4-N TOTAL (mg/L)	0.04		0.04	0.04		1
Nitrate, Total (mg/L as N)	0.75	0.74	1.05	0.38	0.21	20
Nitrogen, Total Kjeldahl (TKN) (mg/L as N)	0.19	0.2	0.3	0.1	0.07	19
Orthophosphorus, Dissolved (mg/L as P)	0.02	0.02	0.1	0.01	0.02	16
Phosphorus, Total (mg/L as P)	0.06	0.06	0.1	0.01	0.04	10
Solids, Total (mg/L)	144.35	138	212	95	35.06	20
Solids, Total dissolved (TDS) (mg/L)	131	122	199	85	34	19
Solids, Total inorganic (mg/L)	111.65	111.5	168	69	28.08	20
Solids, Total inorganic suspended (mg/L)	6.53	5	22	1	6.13	15
Solids, Total organic (mg/L)	32.7	33	53	14	10.63	20
Solids, Total organic suspended (mg/L)	3.5	2.5	12	1	3.01	16
Solids, Total suspended (TSS) (mg/L)	8.56	7	32	1	7.81	18
Sulfate, Total (mg/L)	12.72	11.25	22.05	9.1	3.48	18
Temperature (Celsius)	13.98	14.05	25.2	4.5	6.39	20
Total Hardness CACO3 (mg/L)	116.15	107	162	68	31.01	20
Total Organic Carbon (TOC) (mg/L)	1.63	1.28	5	0.6	0.98	20
Turbidity JTU	6.18	4.75	25	1.5	5.31	20
Sediment Metals						
Arsenic, Sediment (mg/kg dry wt)	9	9	13	5	5.66	2
Chromium, Sediment (mg/kg dry wt)	17.5	17.5	18	17	0.71	2
Copper, Sediment (mg/kg dry wt)	26.5	26.5	37	16	14.85	2
Lead, Sediment (mg/kg dry wt)	78.5	78.5	140	17	86.97	2
Nickel, Sediment (mg/kg dry wt)	20	20	25	15	7.07	2
Zinc, Sediment (mg/kg dry wt)	78	78	82	74	5.66	2

[1]SD: standard deviation, [2]N: number of sample measurements.

Table 2.15 Single sample in-stream water quality data at 6CNFH083.32 (9/1990).

Water Quality Constituent	Value
Water Column Metals	
Copper, Total (µg/L)	10
Iron, Total (µg/L)	230
Manganese, Total (µg/L)	30
Nitrite, Total (mg/L as N)	0.01
Sediment Metals	
Selenium, Sediment (mg/kg dry wt)	6

Table 2.16 Single sample in-stream water quality data at 6CNFH083.94 (5/2002).

Water Quality Constituent	Value
Conductivity (µmhos/cm)	1,880
Field_pH (std units)	8.29
Nitrate, Total (mg/L as N)	0.36
Nitrogen, Total Kjeldahl (TKN) (mg/L as N)	0.1
Phosphorus, Total (mg/L as P)	0.01
Solids, Inorganic suspended (mg/L)	3
Solids, Total (mg/L)	127
Solids, Total inorganic (mg/L)	97
Solids, Total suspended (TSS) (mg/L)	5
Solids, Total volatile (mg/L)	30
Temperature (Celsius)	19.8
Total Hardness CACO3 (mg/L)	84.2
Sediment Metals	
Chromium, Sediment (mg/kg dry wt)	10
Copper, Sediment (mg/kg dry wt)	11
Lead, Sediment (mg/kg dry wt)	14
Manganese in mud (mg/kg dry wt)	232
Nickel, Sediment (mg/kg dry wt)	8.24

Table 2.17 In-stream water quality data at 6CNFH085.20 (1/90-3/05).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Alkalinity (mg/L)	99.5	89.6	152	56.3	29.31	20
BOD5 (mg/L)	1.05	1	2	1	0.23	19
Chloride, Total (mg/L)	17.68	2.95	301	1.7	66.69	20
COD (mg/L)	5.35	5.2	12	1	2.97	20
Conductivity (µmho/cm)	206.66	197.6	359	10.6	59.44	53
Dissolved Oxygen (DO) (mg/L)	10.45	10.1	15.56	7.33	2.19	32
Field pH (std units)	8.02	8.05	8.73	7.11	0.32	52
Fluoride, Total (mg/L)	0.1	0.1	0.13	0.06	0.02	5
NH3+NH4-N TOTAL (mg/L)	0.04	0.04	0.04	0.04	0	2
Nitrate, Total (mg/L as N)	0.68	0.65	1.06	0.36	0.21	43
Nitrite, Total (mg/L as N)	0.01	0.01	0.01	0.01	0	9
Nitrogen, Total (mg/L)	0.76	0.74	0.88	0.6	0.1	10
Nitrogen, Total Kjeldahl (TKN) (mg/L as N)	0.21	0.2	1.2	0.1	0.18	37
Orthophosphorus, Dissolved (mg/L as P)	0.01	0.01	0.02	0.01	0	14
Orthophosphorus, Total (mg/L as P)	0.02	0.02	0.03	0.02	0	9
Phosphorus, Total (mg/L as P)	0.03	0.02	0.1	0.01	0.02	42
Solids, Total inorganic suspended (mg/L)	7.68	5	36	1	8.41	22
Solids, Total (mg/L)	137.33	129	466	18	57.98	51
Solids, Total dissolved (TDS) (mg/L)	117	111	186	80	28	17
Solids, Total inorganic (mg/L)	109.29	100.5	424	48	56.44	42
Solids, Total organic mg/L	32.6	31.5	66	8	12.07	42
Solids, Total suspended (TSS) (mg/L)	8.53	6	43	1	8.82	36
Sulfate, Total (mg/L)	12	10.75	20.16	8.8	3.06	20
Temperature (Celsius)	12.99	11.5	24.4	0.28	6.81	53
Total Hardness CACO3 (mg/L)	101.93	96	164	51.6	31.65	43
Total Organic Carbon (TOC) (mg/L)	1.67	1.4	5.48	0.67	1.11	20
Total Volatile Suspended Solids mg/L	3.29	2	9	1	2.52	17
Turbidity (JKSN JTU)	6	3.8	24	1.48	5.48	20
Turbidity Hach Turbidimeter FTU	3.88	3.15	8.1	0.49	2.57	20
Turbidity, Lab NTU	7.64	4.3	34	1.8	8.7	13
		Sediment Metals				
Chromium, Sediment (mg/kg dry wt)	13	13	15	11	2.83	2
Copper, Sediment (mg/kg dry wt)	16	16	22	10	8.49	2
Lead, Sediment (mg/kg dry wt)	22.5	22.5	26	19	4.95	2
Nickel, Sediment (mg/kg dry wt)	20.5	20.5	26	15	7.78	2
Selenium, Sediment (mg/kg dry wt)	9	9	14	4	7.07	2
Zinc, Sediment (mg/kg dry wt)	96.5	96.5	120	73	33.23	2

[1]SD: standard deviation, [2]N: number of sample measurements.

Table 2.18 Single sample in-stream water quality data at 6CNFH085.20 (3/1990).

Water Quality Constituent	Value
Water Column Metals	
Iron, Total (µg/L)	190
Magnesium, Total (mg/L)	20
Zinc, Total (µg/L)	10
Sediment Metals	
Arsenic, Sediment (mg/kg dry wt)	4
Beryllium, Sediment (mg/kg dry wt)	1

Table 2.19 In-stream water quality data at 6CNFH089.25 (5/92-3/01).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Alkalinity (mg/L)	95.83	90.95	206	30.7	34.39	102
BOD5 (mg/L)	1.36	1	3	1	0.6	26
Chloride, Total (mg/L)	4.07	3.6	9.6	1.3	1.81	67
COD (mg/L)	9.04	8	31.3	2.3	4.89	57
Conductivity (µmho/cm)	198	196	329	73	68	104
Dissolved Oxygen (DO) (mg/L)	10.12	9.76	15.81	6.28	2.2	101
Field pH (std units)	7.73	7.7	8.44	6.9	0.32	102
NH3+NH4-N TOTAL (mg/L)	0.06	0.05	0.12	0.04	0.03	7
Nitrate, Total (mg/L as N)	0.54	0.54	0.92	0.22	0.17	100
Nitrite, Total (mg/L as N)	0.02	0.02	0.05	0.01	0.01	24
Nitrogen, Total Kjeldahl (TKN) (mg/L as N)	0.25	0.2	1.4	0.1	0.18	95
Orthophosphorus, Total (mg/L as P)	0.02	0.02	0.08	0.01	0.01	65
Phosphorus, Total (mg/L as P)	0.03	0.02	0.29	0.01	0.04	94
Solids, Inorganic suspended (mg/L)	15.09	5	200	2	31.68	58
Solids, Total (mg/L)	142.56	142.5	299	75	40.95	102
Solids, Total dissolved (TDS) (mg/L)	162	125	7164*	54	356	100
Solids, Total inorganic (mg/L)	105.35	105	260	47	33.73	102
Solids, Organic suspended (mg/L)	6.35	2.5	31	1	7.9	20
Solids, Total organic (mg/L)	37.21	35	75	2	14.28	102
Solids, Total suspended (TSS) (mg/L)	15.96	6	231	3	34.33	68
Sulfate, Total (mg/L)	12.47	10.9	40	5.7	5.23	102
Temperature (Celsius)	13.47	14.1	26.6	0.1	7.59	102
Total Hardness CACO3 (mg/L)	109.21	110	182	39.5	35.83	103
Total Organic Carbon (TOC) (mg/L)	2.59	2.2	9.7	1	1.7	48
Turbidity Field (NTU)	12.42	2.2	195	0.62	38.42	26
Turbidity Hach Turbidimeter FTU	7.21	3.7	90	0.19	14.63	77
Water Column Metals						
Iron, Total (µg/L)	168.28	129.29	356.11	79.75	109.09	5
Magnesium, Total (mg/L)	11,060	12,550	16,770	5,270	4,889	5
Manganese, Total (µg/L)	19.71	20.13	26.44	12.13	6.03	4
Sediment Metals						
Aluminum in mud (mg/kg dry wt)	12,916	13,200	16,800	10,000	2,555	5
Antimony, Sediment (mg/kg dry wt)	8	8	10	6	2.83	2
Arsenic, Sediment (mg/kg dry wt)	6.17	6	8	5	1.17	6
Chromium, Sediment (mg/kg dry wt)	16.96	16.7	21	14	2.31	7
Copper, Sediment (mg/kg dry wt)	16.16	15	25	9	5.72	7
Iron in mud (mg/kg dry wt)	20,191	20,600	21,657	18,400	1,320	5
Lead, Sediment (mg/kg dry wt)	20.47	21	25	11	4.93	7
Manganese in mud (mg/kg dry wt)	901.8	889	1,310.00	707	246.14	5
Nickel, Sediment (mg/kg dry wt)	25.68	25.5	32	20	5.59	6
Zinc, Sediment (mg/kg dry wt)	97.19	96	149	16	46.57	7

[1]SD: standard deviation, [2]N: number of sample measurements.

Table 2.20 Single sample in-stream water quality data at 6CNFH089.25 (8/2000).

Water Quality Constituent	Value
Water Column Metals	
Aluminum, Dissolved (µg/L)	12
Arsenic, Dissolved (µg/L)	0.7
Calcium, Dissolved (mg/L)	27.8
Copper, Dissolved (µg/L)	0.7
Copper, Total (µg/L)	16.19
Magnesium, Dissolved (mg/L)	6.8
Manganese, Dissolved (µg/L)	5.6
Nickel, Dissolved (µg/L)	0.7

Table 2.21 In-stream water quality data at 6CNFH097.67 (1/90-10/91).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Alkalinity (mg/L)	122	127	160	86	21.83	21
BOD_5 (mg/L)	1.22	1	2	1	0.43	18
Chloride, Total (mg/L)	2.35	2.29	3.89	1.8	0.48	21
COD (mg/L)	8.27	5.5	60	2.5	12.16	21
Conductivity (µmhos/cm)	245.47	254	299	190	32.53	21
Dissolved Oxygen (DO) (mg/L)	10.57	10.3	13.1	8.2	1.56	20
Field pH (std units)	8.46	8.495	8.77	7.98	0.19	20
Fluoride F, Total mg/L	0.09	0.1	0.13	0.04	0.03	7
NH3+NH4-N TOTAL (mg/L)	0.04					1
Nitrite, Total (mg/L AS N)	0.01					1
Nitrate, Total (mg/L AS N)	0.91	0.835	1.39	0.49	0.29	20
Nitrogen, Total Kjeldahl (TKN) (mg/L as N)	0.184	0.2	0.3	0.1	0.069	19
Orthophosphorus, Dissolved (mg/L AS P)	0.0121	0.01	0.02	0.01	0.004	14
Solids, Total (mg/L)	148.48	148	191	114	21.89	21
Solids, Total dissolved (mg/L)	132	128	161	110	17	12
Solids, Total inorganic suspended (mg/L)	5.09	3	27	1	7.45	11
Solids, Total inorganic (mg/L)	114.9	111	158	90	17.96	21
Solids, Total organic (mg/L)	33.62	33	67	16	10.67	21
Solids, Total organic suspended (mg/L)	3.07	2	9	1	2.09	14
Solids, Total suspended (mg/L)	5.82	5	31	1	6.98	17
Sulfate, Total (mg/L)	5.83	6.07	8.4	4.7	0.87	21
TEMP (Celsius)	13.7	14.4	22.4	4.7	5.62	21
Total Hardness CACO3 (mg/L)	126.19	128	156	88	20.65	21
Total Organic Carbon (mg/L)	1.643	1.4	5.66	0.64	1.035	21
Total Phosphorus (mg/L AS P)	0.051	0.03	0.1	0.01	0.04	11
Turbidity Hach Turbidimeter FTU	2.16	1.745	5.1	1.2	1.15	10
Turbidity JKSN (JTU)	4.19	2.8	17	0.6	3.55	21
Sediment Metals						
Arsenic, Sediment (mg/kg dry wt)	8.33	8	11	6	2.52	3
Chromium, Sediment (mg/kg dry wt)	16.33	16	18	15	1.53	3
Copper, Sediment (mg/kg dry wt)	14.33	15	19	9	5.03	3
Lead, Sediment (mg/kg dry wt)	23	19	31	19	6.93	3
Nickel Sediment (mg/kg dry wt)	16.33	16	20	13	3.51	3
Se, Sediment (mg/kg dry wt)	10	10	18	2	11.31	2
Zinc, Sediment (mg/kg dry wt)	61	60	75	48	13.5	3

[1]SD: standard deviation, [2]N: number of sample measurements.

Table 2.22 Single sample in-stream water quality data at 6CNFH097.67 (9/1990).

Water Quality Constituent	Value
Water Column Metals	
Copper, Total (µg/L)	10
Iron, Total (µg/L)	100
Manganese, Total (µg/L)	10
Sediment Metals	
Thallium, Sediment (mg/kg dry wt)	3

Table 2.23 In-stream water quality data at 6CNFH098.47 (4/95-9/02).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Conductivity (µmhos/cm)	238	250	293	150	52	9
Dissolved Oxygen (DO) (mg/L)	10.0	10.2	13.8	7.6	2.3	9
Field_pH (std units)	8.0	8.0	9.0	7.0	1.0	9
Temperature (Celsius)	16.0	18.0	22.0	6.0	6.0	9

[1]SD: standard deviation, [2]N: number of sample measurements.

Table 2.24 Single sample in-stream water quality data at 6CNFH108.76 (5/2002).

Water Quality Constituent	Value
Conductivity (µmhos/cm)	187
Field_pH (std units)	8.15
Nitrate, Total (mg/L as N)	0.39
Nitrogen, Total Kjeldahl (TKN) (mg/L as N)	0.1
Phosphorus, Total (mg/L as P)	0.01
Solids, Total (mg/L)	124
Solids, Total inorganic (mg/L)	102
Solids, Total organic (mg/L)	22
Temperature (Celsius)	18.3
Total Hardness CACO3 (mg/L)	71
Turbidity Hach Turbidimeter FTU	2
Sediment Metals	
Chromium, Sediment (mg/kg dry wt)	7
Copper, Sediment (mg/kg dry wt)	5
Lead, Sediment (mg/kg dry wt)	10
Manganese in mud (mg/kg dry wt)	610
Nickel, Sediment (mg/kg dry wt)	8
Zinc, Sediment (mg/kg dry wt)	36

Table 2.25 In-stream water quality data at 6CNFH113.36 (8/01-6/03).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Conductivity (µmhos/cm)	269	264	307	219	29	12
Dissolved Oxygen (DO) (mg/L)	11.27	11.2	14.33	8.41	1.91	11
Field pH (std units)	8.24	8.24	8.55	7.94	0.16	12
Nitrate, Total (mg/L as N)	0.97	1	1.82	0.46	0.4	12
Nitrite, Total (mg/L as N)	0.01	0.01	0.01	0.01	0	4
Nitrogen, Total Kjeldahl (TKN) (mg/L as N)	0.17	0.2	0.2	0.1	0.048	10
Solids, Total (mg/L)	167.5	166.5	203	124	22.27	12
Solids, Total inorganic suspended (mg/L)	8.5	5	21	3	8.39	4
Solids, Total inorganic (mg/L)	128.4	124.5	156	108	17.21	12
Solids, Total organic (mg/L)	39.1	38	62	12	12.3	12
Solids, Total organic suspended (mg/L)	5		5	5		1
Solids, Total suspended (mg/L)	8.17	5	26	3	8.89	6
Temp (Celsius)	12.46	12.08	21.47	4.14	5.83	12
Total Hardness CACO3 (mg/L)	134.2	138	155	106	15.1	12
Total Phosphorus (mg/L as P)	0.024	0.02	0.08	0.01	0.022	12
Turbidity Lab (NTU)	9.95	9.95	18	1.9	11.38	2

[1]SD: standard deviation, [2]N: number of sample measurements.

Table 2.26 In-stream water quality data at 6CNFH127.12 (8/01-6/03).

Water Quality Constituent	Mean	Median	Max	Min	SD[1]	N[2]
Conductivity (µmhos/cm)	256.5	259.6	305.6	204.4	33.6	12
Dissolved Oxygen (DO) (mg/L)	10.73	10.48	14.09	8.85	1.67	11
Field pH (std units)	8.17	8.15	8.64	7.86	0.18	12
NH3+NH4-N TOTAL (mg/L)	0.04	0.04	0.04	0.04	0	2
Nitrate, Total (mg/L as N)	0.96	0.9	1.6	0.64	0.28	12
Nitrite, Total (mg/L as N)	0.0117	0.01	0.02	0.01	0.0041	6
Nitrogen, Total Kjeldahl (TKN) (mg/L as N)	0.15	0.1	0.3	0.1	0.071	10
Solids, Total (mg/L)	163.6	168	190	137	18.15	12
Solids, Total inorganic (mg/L)	127.5	129.5	148	109	13.27	12
Solids, Total inorganic suspended (mg/L)	8.29	4	28	4	8.81	7
Solids, Total organic (mg/L)	36.1	35	69	12	12.92	12
Solids, Total organic suspended (mg/L)	6	6	6	6	--	1
Solids, Total suspended (mg/L)	10.57	6	34	5	10.47	7
Temp (Celsius)	12.74	12.85	21.86	4.22	5.44	12
Total Hardness CACO3 (mg/L)	124.7	126.5	144	103	14.3	12
Total Phosphorus (mg/L as P)	0.021	0.02	0.05	0.01	0.011	12
Turbidity Hach Turbidimeter FTU	3.79	3.45	8.1	1.12	2.1	10
Turbidity Lab (NTU)	8.75	8.75	14	3.5	7.42	2

[1]SD: standard deviation, [2]N: number of sample measurements.

2.5.2 VADEQ Special Flow, Conductivity, and Chloride Sampling on the Upper North Fork Holston River

During the spring of 2005 the VADEQ performed special flow, conductivity, and chloride sampling in the vicinity of Saltville to locate the source of the high conductivity and chloride values. The source was a large culvert that drains the Town of Saltville and discharges to the river just below the Rt. 613 bridge at river mile 83.31. The culvert receives overflow from the salt ponds in the Town. Table 2.27 provides the results of the VADEQ sampling.

Table 2.27 VADEQ special monitoring at Saltville culvert near Rt. 613 (river mile 83.31).

Date	Conductivity (μmhos/cm)	Total chloride (mg/L)	Flow (cfs)
4/12/2005	8,000	NA	NA
4/18/2005	NA	3,990	NA
4/21/2005	5,000	1,990	2.45
4/25/2005	10,000	3,940	7.22
5/9/2005	5,000	1,360	1.59
5/12/2005	9,000	2,910	2.83
5/20/2005	6,000	NA	2.68
6/15/2005	9,756	3,150	NA

NA – Not measured or sampled

2.5.3 Fish Tissue and Sediment Results from the Upper North Fork Holston River

VADEQ performed special fish tissue and sediment sampling at several sites on the North Fork Holston River. Tables 2.28 through 2.31 show the results of these sampling events in the upper portion of the North Fork Holston River. The Upper North Fork Holston River is under a Virginia Department of Health (VDH) fish consumption ban due to mercury contamination from an abandoned plant site in Saltville. Table 2.28 indicates that recent fish tissue data finds tissue levels just below the VDH action level of 0.5 ppm; however, they still exceed the EPA recommended screening level of 0.3 ppm. In addition, the ban also includes PCBs but the source is still unknown. More information on the VDH ban can be found at http://www.vdh.state.va.us/HHControl/TennesseeBigSandy.asp. Metals sediment sampling was performed at eight VADEQ ambient monitoring stations between January 1990 and March 2005. The maximum values reported are compared to the Probable Effect

Concentration (PEC) in Table 2.32. Mercury exceeded the PEC value in numerous sediment samples and the data for it is shown in Table 2.33.

Table 2.28 Fish tissue sampling results for mercury and PCBs from 6CNFH078.55 on 6/19/2002.

Fish Species	VDH mercury action level (ppm[1] wet weight basis)	VDH PCB action level (ppb[2] wet weight basis)	Value
Rock Bass	0.5		0.36
Smallmouth Bass	0.5		0.48
Smallmouth Bass		50	50.55
Rock Bass		50	116.56
Northern Hog Sucker		50	60.50

[1]ppm denotes parts per million (aka - mg/kg); wet weight basis, edible fillet
[2]ppb denotes parts per billion (aka - ug/kg or ng/g); wet weight basis, edible fillet

Table 2.29 Special study sediment metals results from the Upper North Fork Holston River.

	STATION	6CNFH097.67	6CNFH078.55
	DATE	07/97	06/02
Metal	**Consensus PEC[1] value (mg/kg)**	**Value (mg/kg)**	**Value (mg/kg)**
Aluminum	NA	0.45	0.69
Silver	NA	0.058	<0.02
Arsenic	33	6	8
Cadmium	4.98	0.25	0.19
Chromium	111	9.4	12
Copper	149	12	20
Mercury	1.06	0.17	**1.1**
Nickel	48.6	1.7	13
Lead	128	20	16
Antimony	NA	<0.5	<0.5
Selenium	NA	<0.5	<0.5
Thallium	NA	<0.3	<0.3
Zinc	459	78	36

[1] PEC Probable Effect Concentration (MacDonald et al., 2000).
BOLD numbers indicate exceedance of the screening value.

Table 2.30 Special study sediment organics results from the Upper North Fork Holston River.

	STATION	6CNFH097.67	6CNFH078.55
	DATE	07/97	06/02
Parameter	**PEC[1] (ug/kg)**	**Value (ug/kg)**	**Value (ug/kg)**
Total PAH[2]	22,800	3,328.34	510.23
High MW[3] PAH	NA	142.80	430.64
Low MW PAH	NA	9.72	79.59
NAP[4]	561		5.64
NAP 2-Me[5]	NA		7.22
NAP 1-Me[6]	NA		5.11
Biphenyl	NA		1.29
NAP d-Me[7]	NA	5.14	4.61
Acenaphthylene	NA		0.65
Acenaphthene	NA		1.41
NAP t-Me[8]	NA		3.89
Fluorine	536		2.22
PHH[9]	1,170	9.72	34.83
ATH[10]	845		5.39
PHH 1-Me	NA	6.07	7.33
FTH[11]	2,230	18.26	59.11
Pyrene	1,520	11.77	46.23
ATH benz(a)	1,050	94.93	30.80
Chrysene	1,290	11.56	37.37
FTH benzo(b)	NA	12.51	45.49
FTH benzo(k)	NA		35.76
Pyrene benzo(e)	NA	9.38	33.82
Pyrene benzo(a)	1,450	6.28	47.09
Perylene	NA	50.27	30.76
Pyrene IND[12]	NA	7.91	27.02
ATH db(a,h)[13]	NA		10.67
Perylene benzo(ghi)	NA	4.78	26.52

[1] PEC Probable Effect Concentration (MacDonald et al., 2000), [2] PAH Polyaromatic hydrocarbon, also polynuclear aromatic hydrocarbons (PNAs), [3] MW Molecular Weight, [4] NAP Naphthalene, [5] NAP 2-Me Methyl, [6] NAP 1-Me Methyl, [7] NAP d-Me, [8] 2,3,5 Trimethyl, [9] Phenanthrene, [10] Anthracene, [11] Fluoranthene, indeno, [12] (1,2,3-cd), [13] dibenzo (a,h)

Table 2.31 Special study sediment PCB and pesticide results from the Upper North Fork Holston River.

	STATION	6CNFH097.67	6CNFH078.55
	DATE	07/97	06/02
Parameter	PEC[1] (ug/kg)	Value (ug/kg)	Value (ug/kg)
Total PCB[2]	676	7.37	6.38
Total[3] Chlordane	17.6	0.25	0.79
Sum DDE[4]	31.3		0.28
Sum DDT[5]	62.9		5.27
Total DDT[6]	572		5.55
Total BDE[7]	NA		1.46
HCB[8]	NA		1.00
OCDD[9]	NA	0.58	0.12

[1] PEC Probable Effect Concentration (MacDonald et al., 2000), [2] Total PCB denotes sum of polychlorinated biphenyl congeners, [3] Total Chlordane denotes sum of chlordane and breakdown products, [4] Sum DDE denotes sum of dichlorodiphenyl dichloroethylene isomers, [5] Sum DDT denotes sum of dichlorodiphenyl trichloroethane isomers, [6] Total DDT denotes sum of isomers of DDE, DDD, and DDT, [7] BDE Total BDE denotes sum of polybrominated diphenyl ether congeners, [8] HCB Hexachlorobenzene, [9] OCDD Octachlorodibenzodioxin

Table 2.32 Sediment metals results from the upper section of the North Fork Holston River.

		Monitoring Station River Mile							
Metal	PEC[1]	59.96	80.43	83.32	83.94	85.20	89.25	97.67	108.76
Antimony, mg/kg	NA	13					10		
Chromium, mg/kg	111	22	21	18	10	15	21	18	7
Copper, mg/kg	149	42	52	37	11	22	25	19	5
Lead, mg/kg	128	52	36	**140**	14	26	25	31	10
Nickel, mg/kg	48.60	22	28	25	8				
Zinc, mg/kg	459	107	151	82	56	120	149	75	36

[1] PEC Probable Effect Concentration (MacDonald et al., 2000)
Bold numbers exceed the PEC value.

Table 2.33 Sediment mercury results from the upper section of the North Fork Holston River.

Date	PEC[1]	6CNFH059.65	6CNFH080.43	6CNFH083.32	6CNFH083.94
3/20/90	1.06	**5.40**			
3/28/90	1.06		**7.36**	**1.30**	
4/3/91	1.06		**3.30**	**2.80**	
4/29/91	1.06	**1.20**			
7/30/91	1.06		**2.40**		
7/13/92	1.06		**4.00**		
7/22/92	1.06	**1.30**			
10/20/94	1.06		**3.46**		
12/5/95	1.06	**5.60**			
7/2/96	1.06		**2.00**		
5/20/97	1.06	**1.54**	**2.00**		
6/3/99	1.06	**1.52**	**1.88**		
5/2/02	1.06				0.42
7/28/03	1.06		**2.42**		

[1]PEC consensus probable effect concentration (MacDonald et. al, 2000)
Bold numbers exceed the PEC value.
All values are in mg/kg.

2.5.4 Dissolved Metals Results from the Upper Section of the North Fork Holston River

Water column dissolved metals were sampled by the VADEQ at stations 6CNFH059.26, 6CNFH080.43, and 6CNFH089.25 on August 9, 2000 and all results for metals with a water quality standard were below the appropriate hardness-based water quality standard. Additional samples were collected on July 28, 2003 at station 6CNFH080.43 and, again, all concentrations for metals with a water quality standard were below the appropriate hardness-based water quality standard (Table 2.34).

Table 2.34 Dissolved metals at VADEQ stations on the upper section of the North Fork Holston River (µg/L).

Metal	Date	6CNFH059.65	6CNFH080.43	6CNFH089.25
Aluminum	8/9/00	13.4		13.4
	Standard	NA	NA	NA
Aluminum	7/28/03		2.44	
	Standard	NA	NA	NA
Arsenic	7/28/03		0.44	
	Standard	NA	NA	NA
Barium	7/28/03		45	
	Standard	NA	NA	NA
Chromium	7/28/03		0.95	
	Standard	NA	4,275	NA
Copper	8/9/00	0.80	0.58	0.70
	Standard	3	41	17.3
Nickel	8/9/00	0.60	0.63	0.70
	Standard	188	389	179

NA - Virginia has no water quality standard

2.5.5 Additional Water Quality Data

Olin Corporation is required by the EPA to collect sediment and tissue mercury data due to a Superfund designation. This data was supplied to the VADEQ and subsequently used for this report. Figures for this data are in Appendix A. The reported fish tissue data was for rock bass, sunfish and northern hogsuckers. The invertebrate tissue data was collected from crayfish, hellgrammites and Asiatic clams.

A Superfund site at Saltville carries EPA permit number VAD003127578. The former Olin Matheson Plant operated from 1950 to 1972 and produced chlorine and caustic soda. The production process required the mining of salt and the use of mercury. This is the source of the mercury contamination in the Upper North Fork Holston River. It is estimated that during its time of operation 1,814 metric tons of mercury was deposited in the plant's settling ponds (also known as "muck ponds"). The Olin Corporation completed the construction of an impermeable cap over the 75-acre waste disposal area known as Pond 5 and a permeable cap over the 45-acre waste disposal area known as Pond 6 during Fall 2002. A wildlife habitat area has been created on the former disposal ponds. Olin is operating an on-site water treatment plant for leachate from Ponds 5 and 6. The Saltville site has no untreated surface water discharging to the Upper North Fork Holston River.

There has been extensive salt mining in the Saltville area since salt was first discovered in the region in 1840. The NUI-Virginia Gas Company is currently producing salt at its Saltville Gas Storage Facility. The company bought the rights to a number of abandoned high pressure wells owned by Olin Corporation. NUI-Virginia Gas uses the brine from the wells to make salt. The company discharges from outfall 001 to McHenry Creek under Virginia Pollutant Discharge Elimination System (VPDES) permit number VA0090115. In September 2004, a brine and condensate spill was discharged from outfall 001 and resulted in a total fish kill for about 3.5 miles in McHenry Creek. The VADEQ determined that 2,130 fish were killed and the NUI-Virginia Gas Company paid the required fine. A chloride concentration of 78,400 mg/L in the effluent was measured by the company in September 2004. However, conductivity and chloride levels quickly returned to normal following the spill. VPDES permit VA0090115 contains reporting requirements for total dissolved solids and conductivity but no permitted limit. A daily average permit limit of 376 (mg/L) for total chloride is also contained in the permit. NUI-Virginia Gas installed some safety equipment to prevent a reoccurrence of a spill.

U.S. Gypsum Company, operating under VPDES permit VA0000876, has not actively mined gypsum for several years. At the present time they are preparing to shut down their facilities.

Special toxicity testing sampling was done as part of the November 2004 TMDL special study conducted by VADEQ at station 6CNFH080.43 to determine water toxicity. The sample was analyzed by the EPA Wheeling, West Virginia Biology Group and no toxicity was found.

2.6 VPDES Permitted Discharges in the Upper North Fork Holston River Watershed.

There are eight VPDES permitted discharges in the Upper North Fork Holston River watershed. These are listed in Table 2.35 and shown in Figure 2.3.

Table 2.35 VPDES permitted discharges in the Upper North Fork Holston River watershed.

Permit No	Facility Name	Class	Design Flow (MGD)	Chloride VPDES Permit Limit (mg/L)	Receiving Stream	River Mile	TYPE
VA0026808	Saltville Town - WWTP	Active	.5000	NA	Upper North Fork Holston River	83.17	VPDES Individual
VA0000876	United States Gypsum Company - Plasterco Plant	Active	.5000	NA	Keywood Branch	0.98	VPDES Individual
VA0070840	PCS Phosphate Company Incorporated - Saltville	Inactive	NA	NA	Upper North Fork Holston River	83.9	VPDES Individual
VA0090115	Saltville Gas Storage Facility	Active	.575	376	McHenry Creek	2.21	VPDES Individual
VAR050116	Svedala Industries, Inc	Inactive	NA	NA	Upper North Fork Holston River	UNK	Industrial Stormwater
VAR050120	Titan Wheel Corporation of Virginia	Active	NA	NA	Upper North Fork Holston River	UNK	Industrial Stormwater
VAG400080	Private Residence STP	Active	<1,000 gpd	NA	Robertson Branch, UT	UNK	Single Family Home
VAG400145	Private Residence STP	Active	<1,000 gpd	NA	Watson Gap Branch, UT	UNK	Single Family Home

NA – not applicable, UNK - unknown

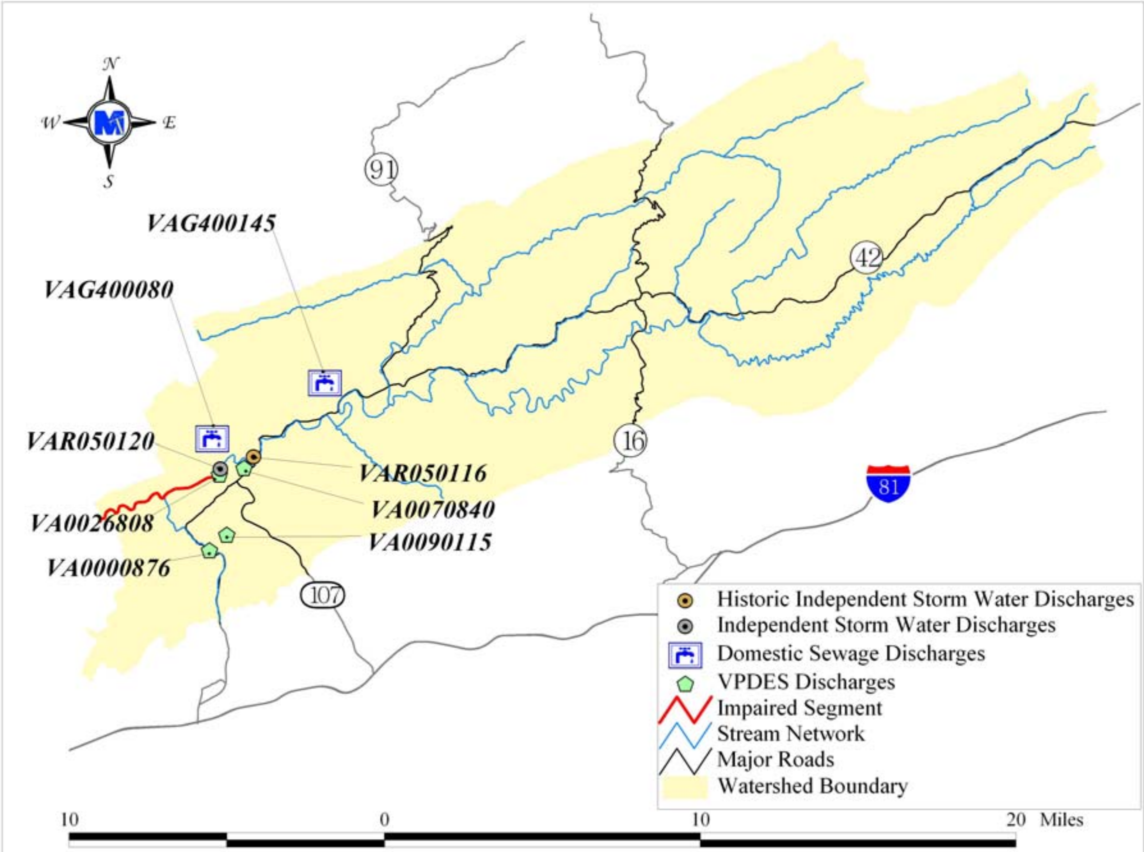

Figure 2.3 Permitted discharges in the Upper North Fork Holston River watershed.

3. TMDL ENDPOINT: STRESSOR IDENTIFICATION – UPPER NORTH FORK HOLSTON RIVER

3.1 Stressor Identification

The North Fork Holston River begins in southwestern Bland County and flows through four additional counties (Tazewell, Smyth, Washington and Scott) before reaching the Virginia/Tennessee state boundary. The river is approximately 135 miles long in Virginia. The impaired section begins at the Robertson Branch confluence at Saltville (river mile 83.56) and extends downstream for 4.79 stream miles to the Tumbling Creek confluence (river mile 78.77). The Upper North Fork Holston River watershed area, from the Tumbling Creek confluence upstream to its headwaters, is 74% forest, 22% pasture, 2% crop, and 0.5% residential. The Upper North Fork Holston River is a fourth order stream at the impaired segment. In the analysis that follows, parameters that exceed established water quality criteria or screening values within the impaired segment will be graphed. For parameters without established water quality criteria or screening values, a 90th percentile screening value was used. The 90th percentile screening values were calculated from 49 monitoring stations in Southwest Virginia on third and fourth order streams that were used as benthic reference stations or were otherwise found not to have a benthic impairment based on the most recent sampling results. The 90th percentile screening values were used to develop a list of possible stressors. If a parameter does not exceed a water quality standard or a screening value or does not have excessive values, median values will be shown for each monitoring station from downstream to upstream. Data for parameters with more than one but less than nine data points can be found summarized in section 2.5.1. The presence of nine values was selected as a cutoff for stressor identification in order to avoid using data from stations that were not sampled during different seasons of the year or different flow regimes in the Upper North Fork Holston River. However, all data was reviewed to ensure consistency with expected values' ranges in the stream.

TMDLs must be developed for a specific pollutant(s). Benthic assessments are very good at determining if a particular stream segment is impaired or not but they usually do not provide enough information to determine the cause(s) of the impairment. The process outlined in the Stressor Identification Guidance Document (EPA, 2000) was used to separately identify the most probable stressor(s) for the Upper North Fork Holston River. A list of candidate causes was developed from published literature and VADEQ. Chemical and physical monitoring data provided evidence to support or eliminate potential stressors. Individual metrics for the biological and habitat evaluation were used to determine if there were links to a specific stressor(s). Land use data as well as a visual assessment of conditions along the stream provided additional information to eliminate or support candidate stressors. The potential stressors are: sediment, toxics, low dissolved oxygen, nutrients, pH, metals, conductivity/total dissolved solids, temperature, and organic matter.

The results of the stressor analysis for the Upper North Fork Holston River are divided into three categories:

> **Non-Stressor(s)**: Those stressors with data indicating normal conditions, without water quality standard violations, or without the observable impacts usually associated with a specific stressor, were eliminated as possible stressors. A list of non-stressors can be found in Table 3.1
>
> **Possible Stressor(s)**: Those stressors with data indicating possible links, but inconclusive data, were considered to be possible stressors. A list of possible stressors can be found in Table 3.2
>
> **Most Probable Stressor(s)**: The stressor(s) with the most consistent information linking it with the poorer benthic and habitat metrics was considered to be the most probable stressor(s). A list of probable stressors can be found in Table 3.3

3.2 Non-Stressors

Table 3.1 Non-Stressors in the Upper North Fork Holston River.

Parameter	Location in Document
Dissolved oxygen	Section 3.2.1
Temperature	Section 3.2.2
Nutrients	Section 3.2.3
Toxics	Section 3.2.4
Metals (except mercury)	Section 3.2.5
Organic Matter (BOD_5 & total organic carbon)	Section 3.2.6

3.2.1 Low Dissolved Oxygen

Dissolved oxygen (DO) concentrations remained well above the minimum water quality standard at the VADEQ monitoring stations. Dissolved oxygen samples were collected before sunrise (5:15 am) at station 6CNFH081.69 on July 28, 2003 to determine if concentrations remained above water quality standards during the night. Oxygen demand is highest during the early morning hours during the summer months and this can be a time when water quality standards' violations occur. The measurement was 6.45 mg/L, indicating that dissolved oxygen concentrations remain well above the water quality standards even during the critical time periods just before daylight. Median values for the VADEQ monitoring stations on the Upper North Fork Holston River are shown in Figure 3.1. Low dissolved oxygen concentrations are considered a non-stressor.

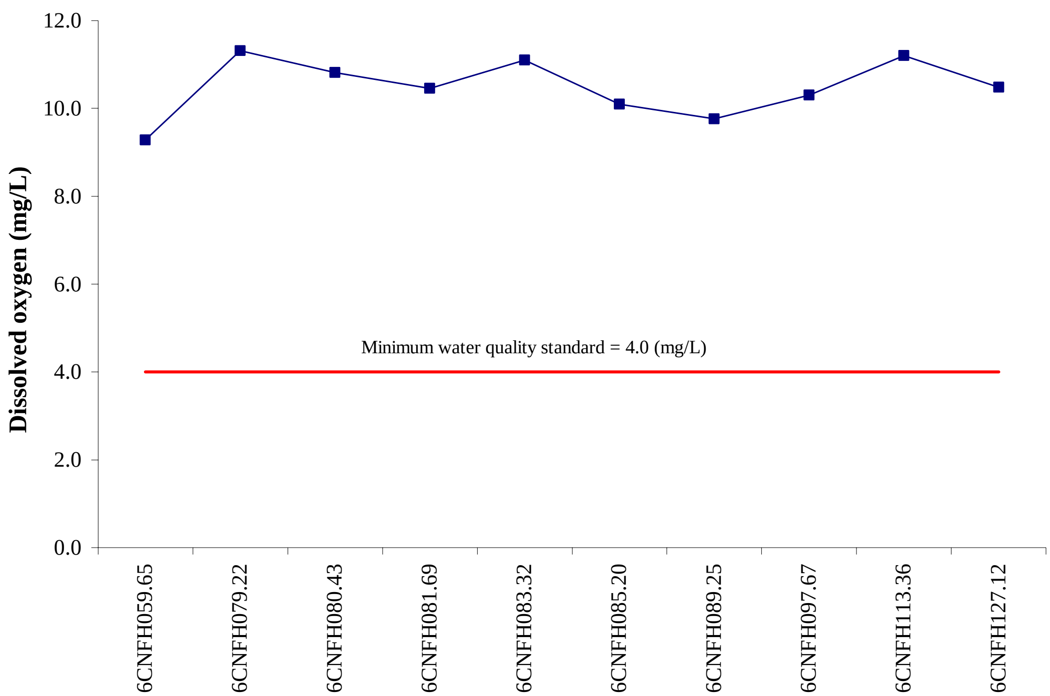

Figure 3.1 Median dissolved oxygen concentrations at VADEQ monitoring stations in the upper portion of the North Fork Holston River.

3.2.2 Temperature

The maximum temperature recorded in the Upper North Fork Holston River was 27.3°C at VADEQ station 6CNFH059.65, which is well below the state standard of 31°C for the mountain zone waters. Median temperature values are shown in Figure 3.2.

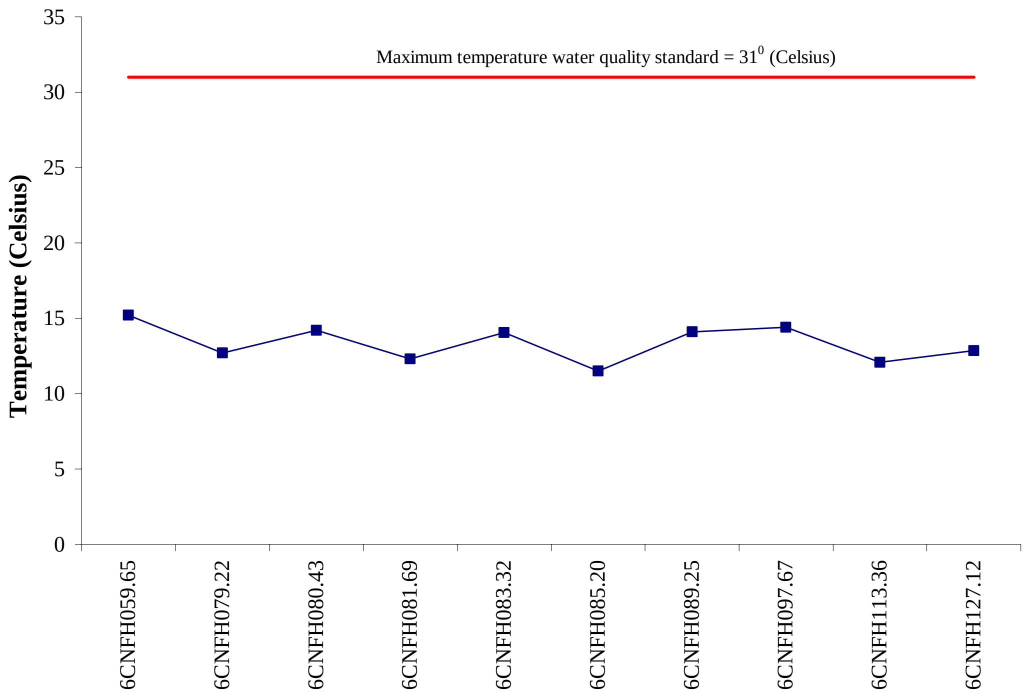

Figure 3.2 Median temperature measurements at VADEQ stations in the upper portion of the North Fork Holston River.

3.2.3 Nutrients

Median Total Phosphorus (TP) concentrations were below the VADEQ assessment screening value of 0.2 mg/L at all of the VADEQ stations. Only one concentration out of 75 samples at VADEQ station 6CNFH080.43 and one concentration out of 94 samples at 6CNFH089.25 exceeded the screening value of 0.2 mg/L (Figures 3.3 and 3.4). Median values for each station are shown in Figure 3.5.

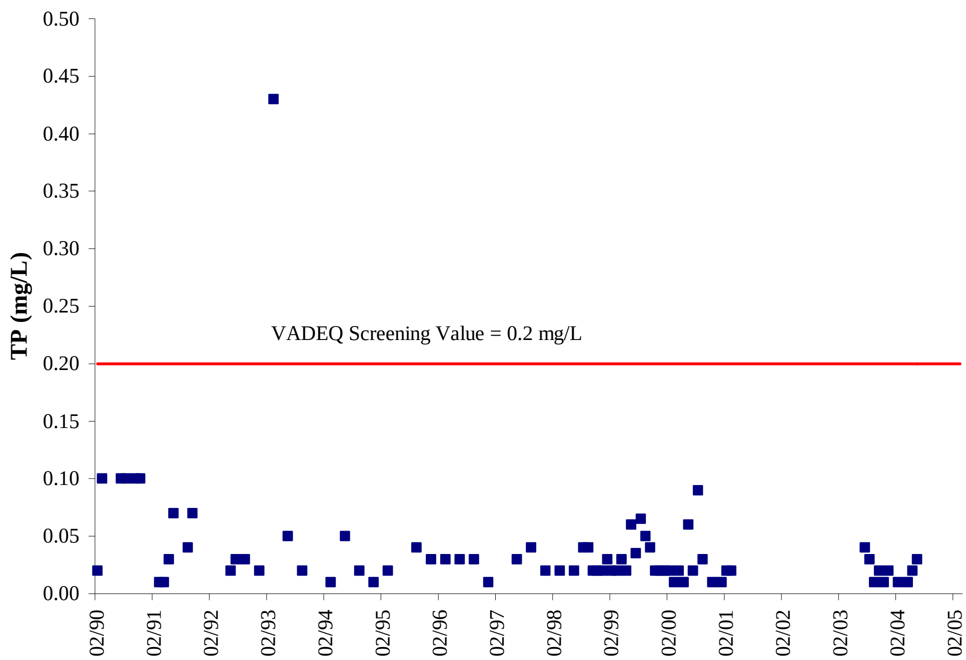

Figure 3.3 Total phosphorus concentrations at VADEQ station 6CNFH080.43 on the Upper North Fork Holston River.

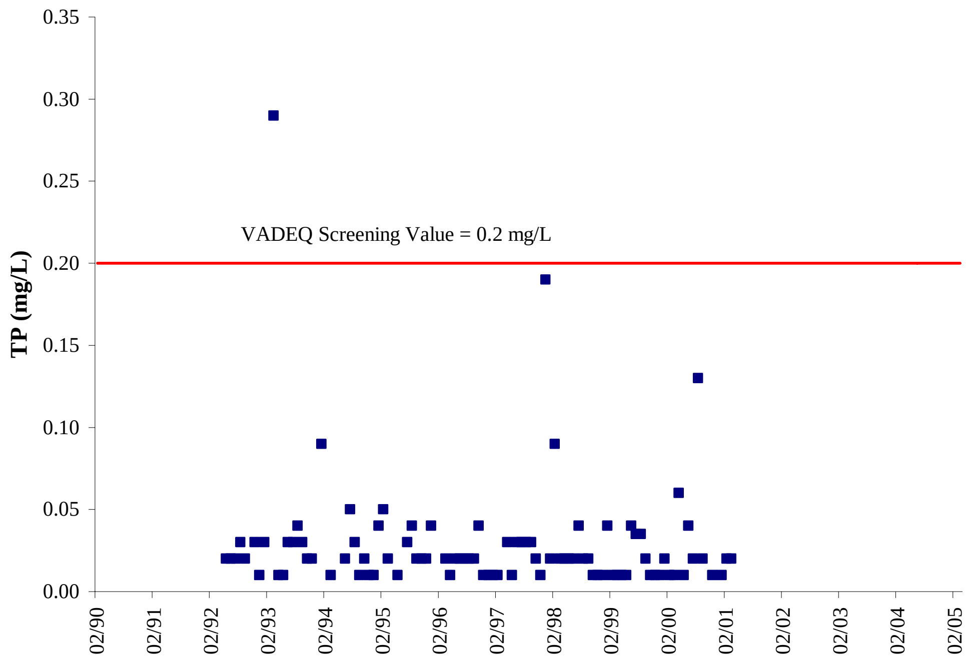

Figure 3.4 Total phosphorus concentrations at VADEQ station 6CNFH089.25 on the Upper North Fork Holston River.

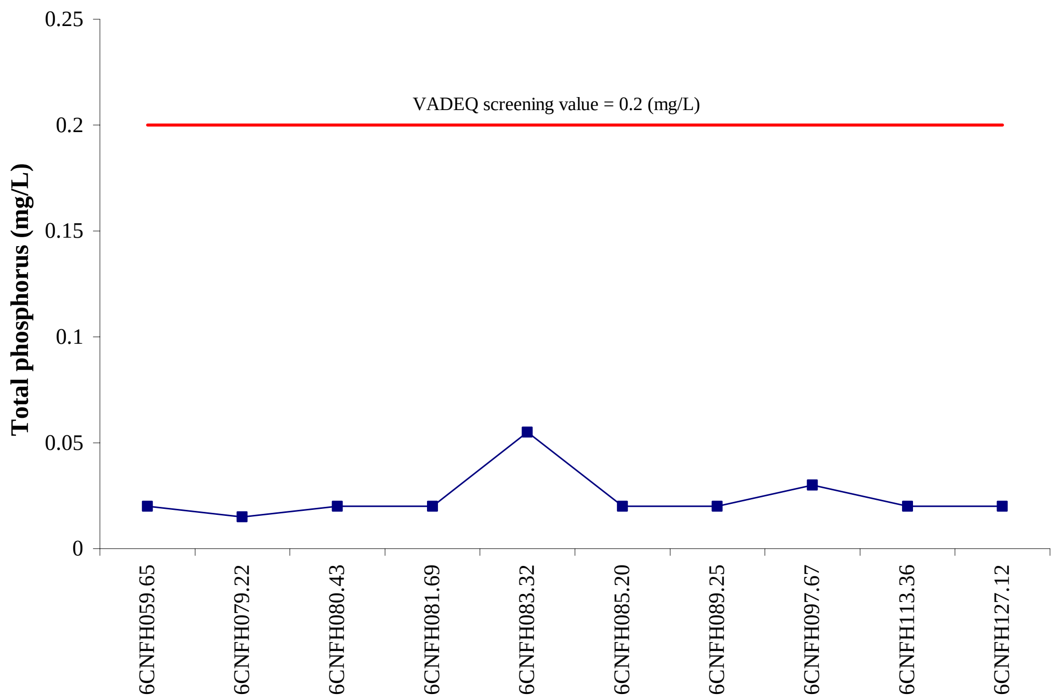

Figure 3.5 Median TP concentrations at VADEQ stations in the upper portion of the North Fork Holston River.

Nitrate nitrogen (NO_3-N) concentrations were all below the 90th percentile screening value (1.23 mg/L) at VADEQ 6CNFH080.43. Concentrations generally decrease moving from upstream to downstream, which indicates dilution from increased stream flow. Median nitrate nitrogen concentrations are shown in Figure 3.6.

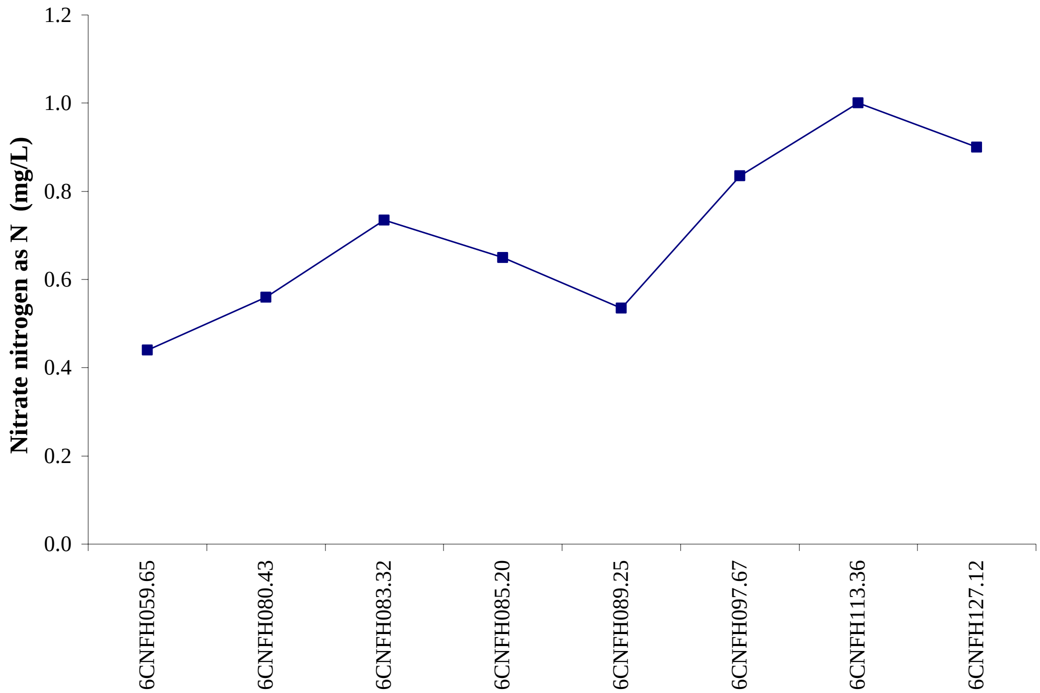

Figure 3.6 Median NO_3-N concentrations at VADEQ stations in the upper portion of the North Fork Holston River.

3.2.4 Toxics

Total ammonia (NH_3/NH_4) concentrations were low at VADEQ station 6CNFH080.43. Figure 3.7 shows the median total ammonia concentrations for the Upper North Fork Holston River. Fish tissue and sediment PCBs, organics, and pesticides were collected at VADEQ station 6CNFH097.67 on July 10, 1997 and station 6CNFH078.55 on June 19, 2002. PCBs in rock bass (116.54 ug/L) and smallmouth bass (60.50 ug/L) exceeded the VDH action value of 50 ug/L. The VDH has issued a fish consumption ban for approximately 80 miles of the North Fork Holston River. More information on the VDH action can be found at http://www.vdh.state.va.us/HHControl/fishingadvisories.asp. All sediment values at these two monitoring stations were below the established PEC (MacDonald et al., 2000) values (see section 2.5.3). The available data supports considering toxics to be non-stressors.

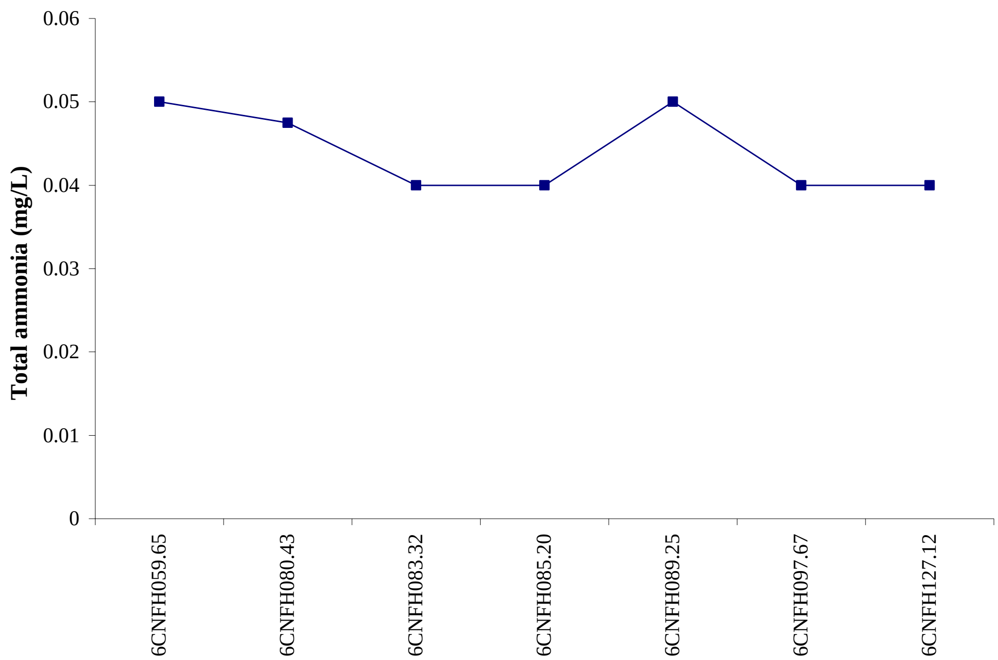

Figure 3.7 Median total ammonia concentrations at VADEQ stations in the upper portion of the North Fork Holston River.

3.2.5 Metals

This section will discuss VADEQ water quality monitoring for metals dissolved in the water column, metals in the sediment, and metals in fish tissue (with the exception of mercury, which will be discussed in section 3.3.2). Sediment and fish tissue metals' data was shown in section 2.5.3. With the exception of mercury, metals' values were below the PEC and VDH action levels where appropriate. Water column dissolved metals' data were shown in section 2.5.4. All results for metals with a water quality standard were below the appropriate hardness-based water quality standard.

VADEQ sediment sampling was performed at five stations in the upper portion of the North Fork Holston River: 6CNFH059.65, 6CNFH083.32, 6CNFH085.20, 6CNFH089.25 and 6CNFH097.67. Two lead sediment samples were collected at 6CNFH083.32 in the early 1990s and one result (140 mg/kg) exceeded the PEC value (128 mg/kg) in April 1991. Eleven lead sediment samples were collected at 6CNFH080.43 (the same general location as the impaired benthic station) between June 1993 and July 2003 and all results were well below the PEC value (Figure 3.8). All of the remaining metals with established PEC values (with the exception of mercury) were below the appropriate PEC value at stations 6CNFH059.65, 6CNFH080.43 and 6CNFH083.32. Based on the results of the dissolved metals, sediment metals, and fish tissue metals data, metals (with the exception of mercury) are considered non-stressors.

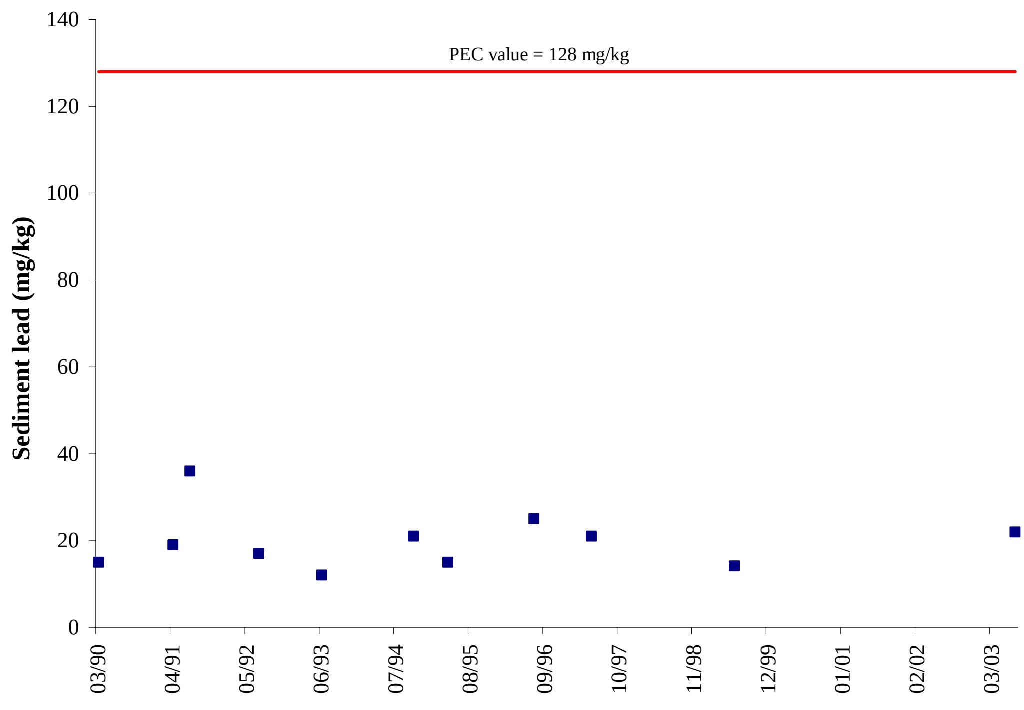

Figure 3.8 Sediment lead values at VADEQ monitoring station 6CNFH080.43.

3.2.6 BOD_5 and Total Organic Carbon

Biochemical oxygen demand (BOD_5) can provide an indication of how much dissolved organic matter is present. Total organic carbon (TOC) also provides an indication of organic matter. BOD_5 and TOC concentrations at 6CNFH080.43 were below the 90th percentile values of 2.0 and 4.0 mg/L, respectively. Median values for each parameter are shown in Figures 3.9 and 3.10. Therefore, BOD_5 and TOC organic matter are considered non-stressors.

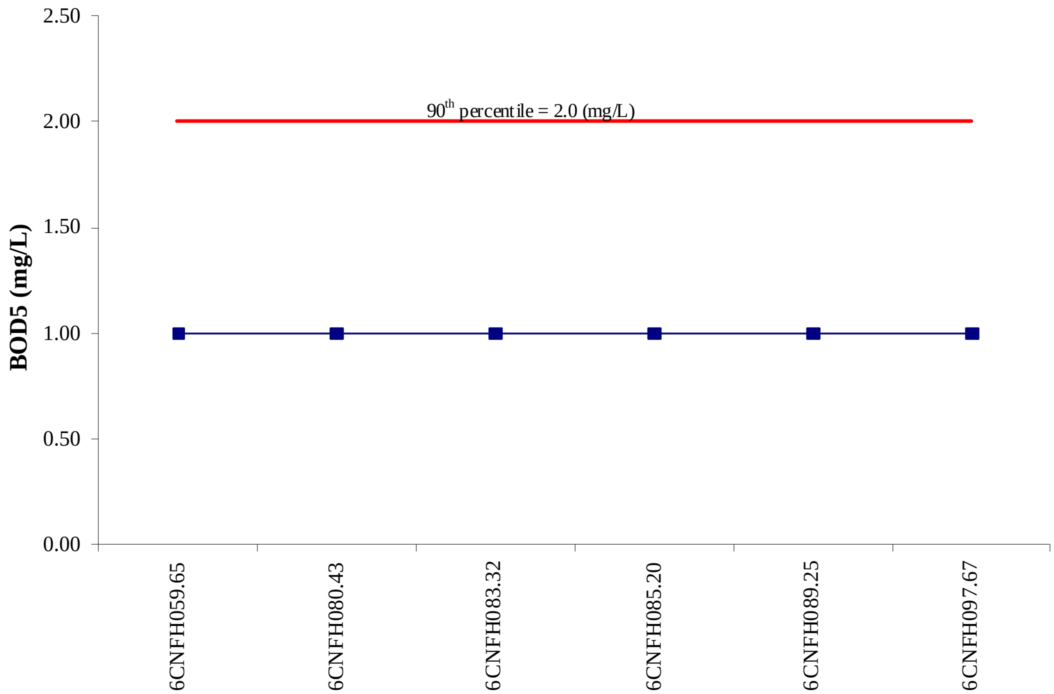

Figure 3.9 Median BOD_5 concentrations at VADEQ stations in the upper portion of the North Fork Holston River.

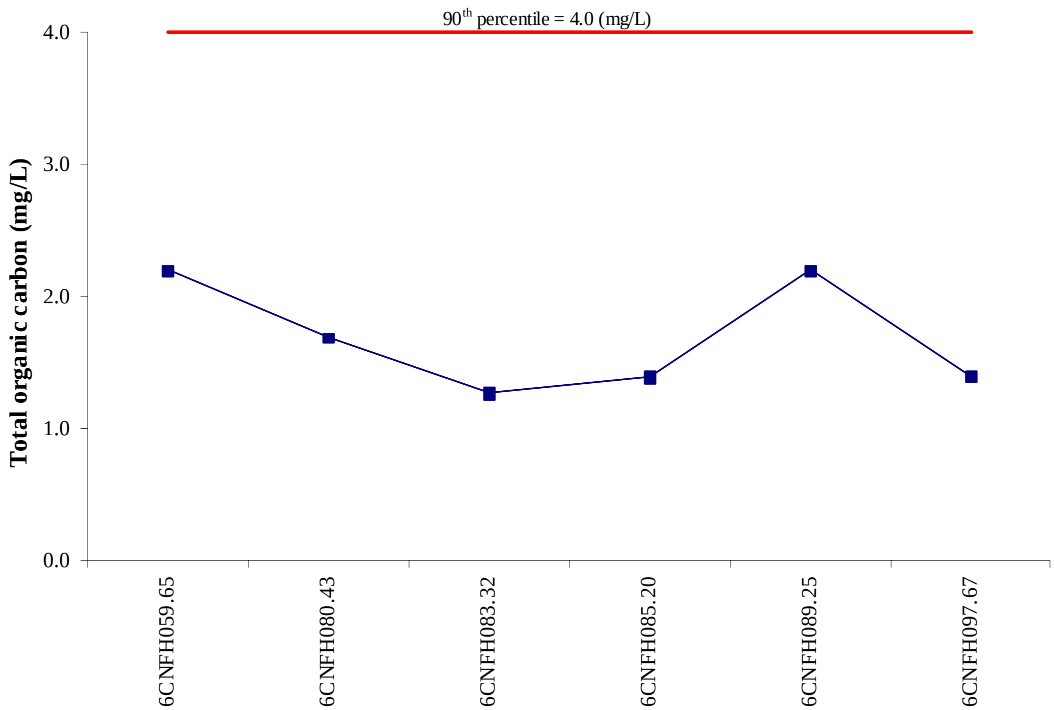

Figure 3.10 Median TOC concentrations at VADEQ stations in the upper portion of the North Fork Holston River.

3.3 Possible Stressors

Table 3.2 Possible stressors in the Upper North Fork Holston River.

Parameter	Location in Document
pH	Section 3.3.1
Mercury	Section 3.3.2
Sediment	Section 3.3.3
Organic matter (COD, TKN & Organic solids)	Section 3.3.4

3.3.1 pH

Field pH was measured at 10 VADEQ water quality monitoring sites. Three values from VADEQ station 6CNFH080.43 exceed the maximum water quality standard of 9.0 std units. The exceptions were in February 1990, April 1990, and March 1991. There have been no additional water quality standards' exceedances at this station (Figure 3.11). Median values for 6CNFH080.43 are consistent with the medians for the other nine VADEQ monitoring stations in the upper portion of the North Fork Holston River. Medians for all 10 stations are shown in Figure 3.12. Because of the three exceedances of the maximum pH standard in the early 1990s, pH is considered a possible stressor.

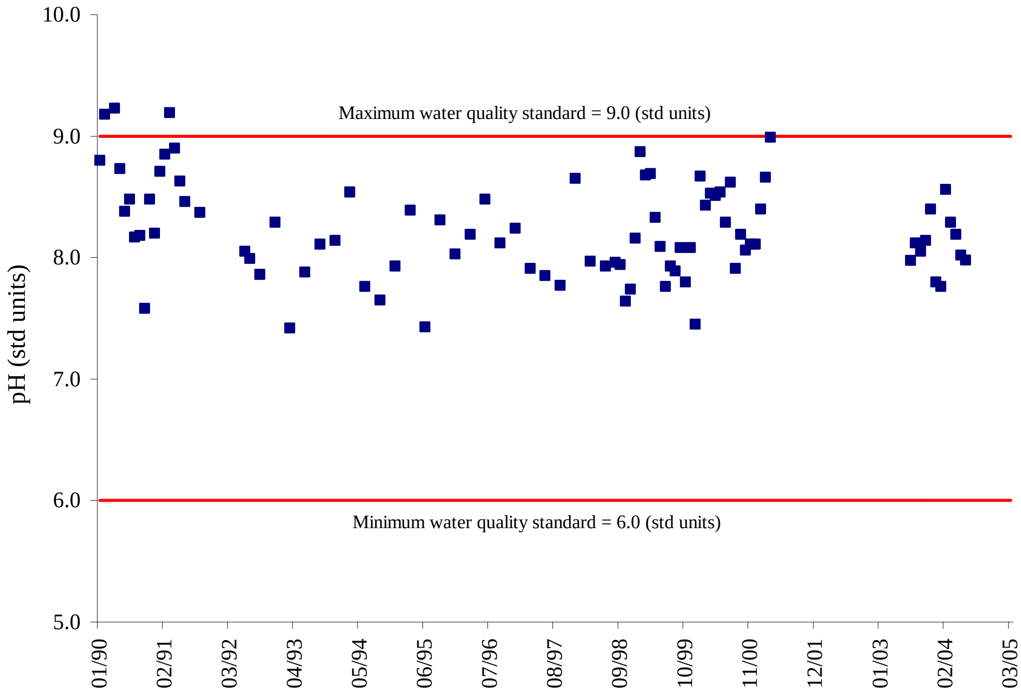

Figure 3.11 Field pH values at VADEQ station 6CNFH080.43.

Figure 3.12 Median field pH values at VADEQ stations in the upper portion of the North Fork Holston River.

3.3.2 Mercury

VADEQ sediment sampling was performed at eight stations in the upper portion of the North Fork Holston River: 6CNFH059.65, 6CNFH080.43, 6CNFH083.32, 6CNFH083.94, 6CNFH085.20, 6CNFH089.25, 6CNFH097.67 and 6CNFH108.76. All 17 mercury values exceeded the PEC value (1.06 mg/kg) at the three most downstream stations: 6CNFH059.65, 6CNFH080.43 and 6CNFH083.32 (Table 2.29). Figures 3.13 and 3.14 show the sediment mercury values collected at 6CNFH059.65 and 6CNFH080.43; only two values were collected at 6CNFH083.32. One mercury sediment sample was collected at 6CNFH083.94 in May 2002 and it was below the PEC Value.

Special study fish tissue and sediment data was collected at one VADEQ station in July 1997 (6CNFH097.67) and a different station in June 2002 (6CNFH078.55). In 2002, mercury in sediment exceeded the PEC value at station 6CNFH078.55 (Table 2.29). In fish tissue data from VADEQ station 6CNFH078.55, mercury exceeded the VADEQ screening value 0.3 (mg/L) in rock bass (0.36 mg/L) and smallmouth bass (0.48 mg/L) in June 2002.

The source of the mercury is the site of the former Olin Matheson plant in Saltville that has been closed since the early 1970s. Section 2.5.5 discusses the activity that has taken place at the former plant site.

Methyl mercury is not typically associated with benthic toxicity; however, there is a PEC value and both the EPA and the VADEQ have aquatic life water quality standards for it. It is obviously bio-available because it is being found in fish tissue. Mercury toxicity is extremely difficult to document because so many different factors influence it. The most important factor is the form mercury is in. Mercury bound to sediments in a stream is usually in the inorganic form and, thus, is not bio-available. It is converted to methyl mercury (the organic form) by sulfur oxidizing bacteria in an environment with high temperatures and low dissolved oxygen concentrations. The amount of nutrients present can also have an impact on methyl mercury formation.

To confirm mercury toxicity in an aquatic environment, the National Oceanic and Atmospheric Administration (NOAA) recommends a site-specific process. A bioaccumulation study in more than one resident and/or transplanted caged species is required. In addition, standard toxicity tests should be conducted and chronic toxicity tests with endpoints on early fish life and reproduction should be included (NOAA, 1996). This type of information is not currently available.

The Tennessee Valley Authority, the U.S. Fish & Wildlife Service, and Olin Corporation are conducting a multi-year Natural Resource Damage Assessment in partnership. The focus of the damage assessment is to determine the impact of mercury on the mussel populations in the watershed. In addition, the EPA and Olin Corporation are carrying out risk assessment work pertaining to the Superfund site. A separate TMDL study will be done for the mercury contamination at a later date. Because much of the data required for determining conclusively whether or not mercury is responsible for some of the benthic impairment in the Upper North Fork Holston River is not available at this time, mercury will be considered a possible stressor for this analysis.

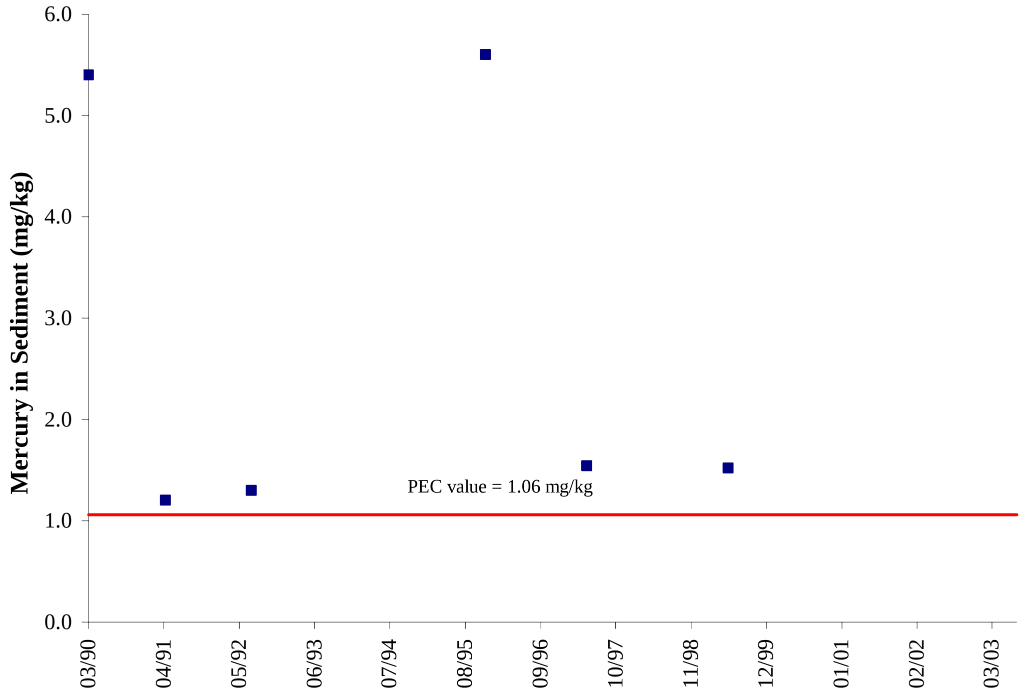

Figure 3.13 Sediment mercury values at VADEQ monitoring station 6CNFH059.65.

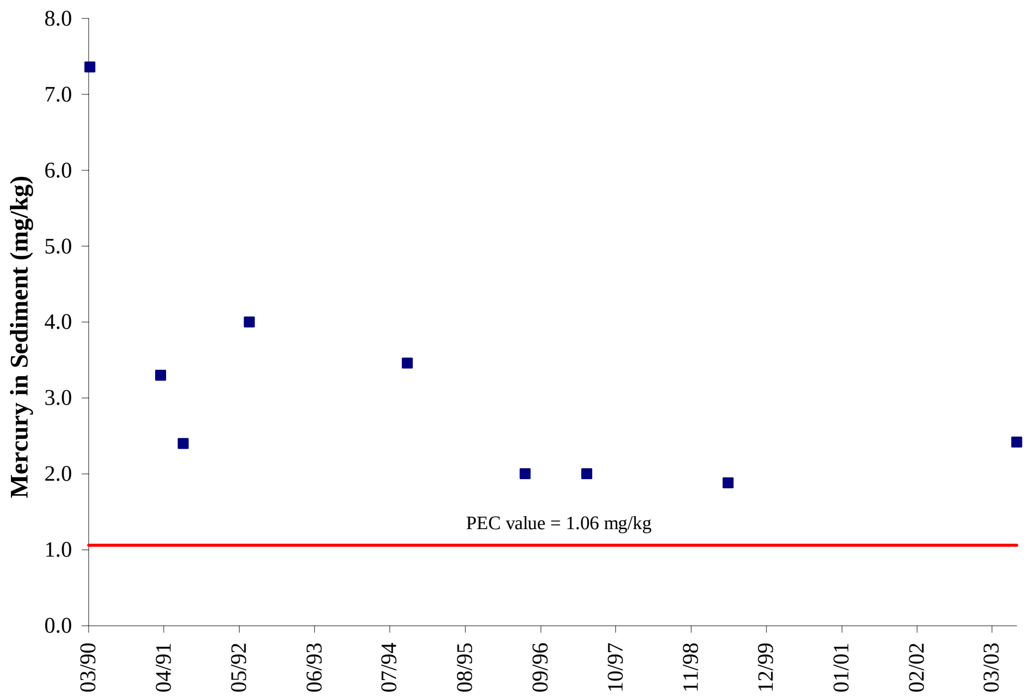

Figure 3.14 Sediment mercury values at VADEQ monitoring station 6CNFH080.43.

3.3.3 Sediment

The Embeddedness habitat scores at VADEQ station 6CNFH080.45 were sub-optimal in the Spring 2003 but marginal in Fall 2003. This metric is one of the best indicators of sediment problems in riffle areas, which contain the majority of the benthic habitat. Pool Sediment scores were marginal for both the spring and fall 2003 surveys. Pool Sediment habitat scores were also marginal for the ecoregion reference station (6CNFH085.31). In addition, the median Pool Sediment and Embeddedness scores for 6CNFH098.47 were marginal and this station was sometimes used as an ecoregion reference station.

A 90^{th} percentile screening value of 30 mg/L was used to determine if total suspended solids concentrations could be considered a problem at 6CNFH080.43. There were occasional spikes over the 15-year monitoring period but less than 10% of the concentrations exceeded the screening value. Median TSS concentrations for the stations with more than nine data points are shown in Figure 3.15.

Sediment is considered a possible stressor because habitat scores at the impaired monitoring station 6CNFH080.45 are similar and consistent to the upstream ecoregion reference stations (6CNFH085.31 and 6CNFH098.47). In the seven benthic surveys conducted at 6CNFH098.47, six had marginal Embeddedness scores but five of the VASCI scores remained well above the 61.3 impairment threshold. The low VASCI scores at 6CNFH080.45 are therefore due to another stressor. Sediment is considered a possible stressor.

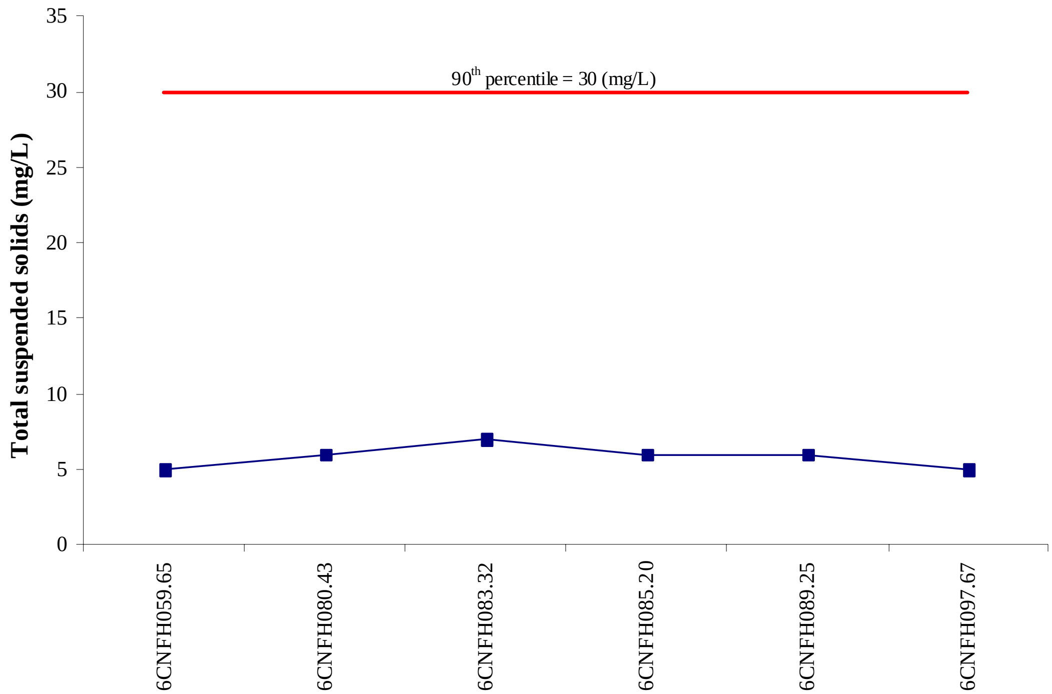

Figure 3.15 Median TSS concentrations at VADEQ stations in the upper portion of the North Fork Holston River.

3.3.4 Organic matter

Several different parameters were used to determine if organic matter in the stream was impacting the benthic macroinvertebrate community. Chemical oxygen demand (COD) and total volatile solids (TVS, also called total organic solids) provide an indication of dissolved oxygen and organic matter. Volatile suspended solids (VSS, also called total organic suspended solids) provide an indication of particulate organic matter in a stream. Total Kjeldahl nitrogen (TKN) is a parameter that indicates how much of the organic matter present is nitrogen-based.

The 90th percentile screening values were calculated for COD (14.0 mg/L), TVS (63 mg/L), VSS (9.0 mg/L), and TKN (0.4 mg/L). Concentrations of COD exceeded the screening value in 12% of the samples collected at 6CNFH080.43 (Figure 3.16). TVS exceeded the screening value at 6CNFH080.43 in 68% of the samples collected and there was a maximum value of 639 mg/L (Figure 3.17). VSS concentrations were relatively low at 6CNFH080.43 and consistent with the other monitoring stations. TKN concentrations at 6CNFH080.43 exceeded the comparison value in 32% of the samples collected with a maximum value of

1.8 mg/L (Figure 3.18). These results indicate that the source of the high organic matter at this monitoring station is dissolved and mostly nitrogen-based. Medians for these parameters at each station can be found in Figures 3.19 – 3.22.

Benthic metrics such as the Modified Family Biotic Index (MFBI) can be an indication of excess organic matter and this metric was typically higher at VADEQ benthic monitoring station 6CNFH080.45 than the reference station it was compared to; however, no score exceeded a value of 5.0. In addition, a family of caddisflies named hydropsychidae (also known as netspinners) are often excellent indicators of excess organic matter. According to Voshell (2002), "If common netspinners account for the majority of the community that is a reliable indicator of organic or nutrient pollution." The benthic assemblage at the impaired VADEQ monitoring station consisted of 18% common netspinners, a fairly low percentage. This indicates that the spikes in dissolved organic matter do not appear to be a significant factor in the shift toward more pollution-tolerant organisms at 6CNFH080.43. For example, the percentage of hydropsychidae in the assemblage of the upstream reference station 6CNFH085.31 is 16%. Based on the number of values that exceeded the screening values, the parameters COD, TKN and TVS are considered possible stressors.

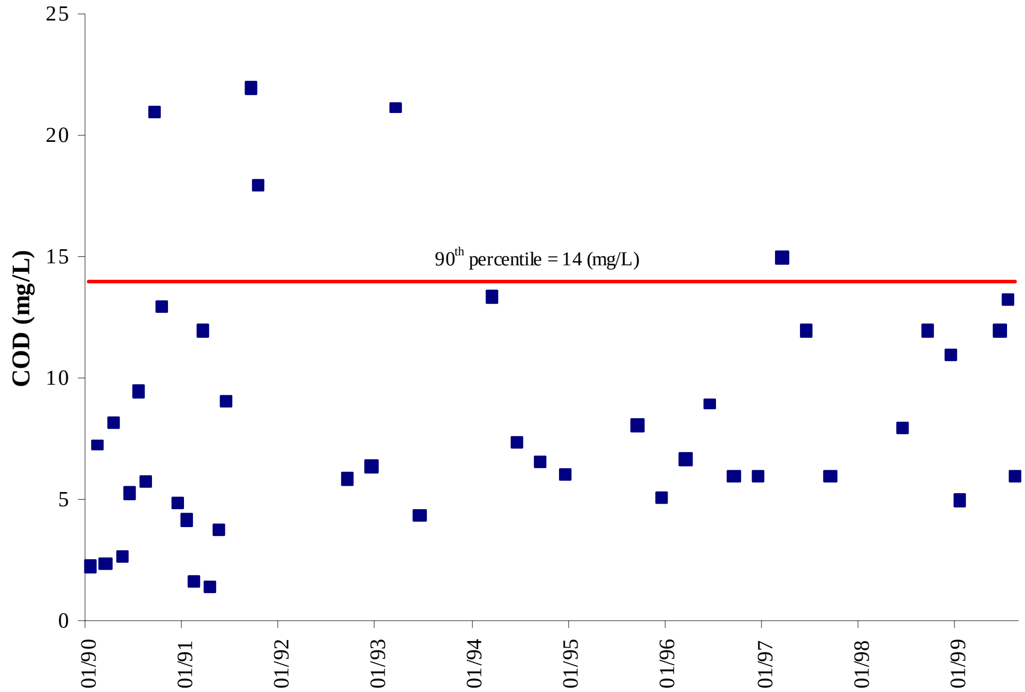

Figure 3.16 COD concentrations at VADEQ station 6CNFH080.43 on the Upper North Fork Holston River.

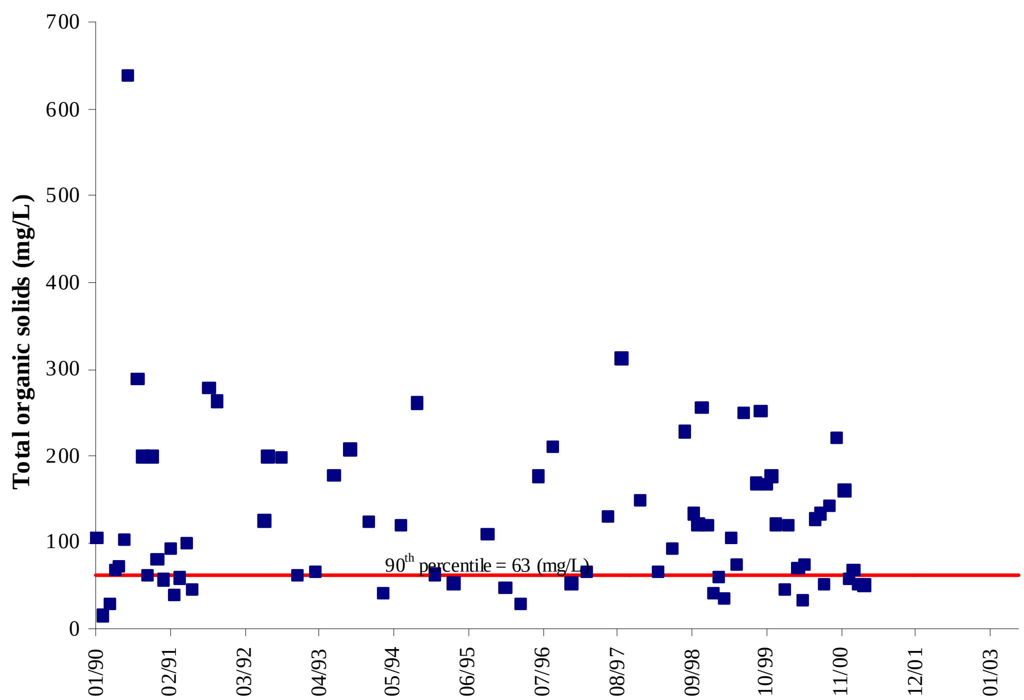

Figure 3.17 Total organic solids concentrations at VADEQ station 6CNFH080.43 on the Upper North Fork Holston River.

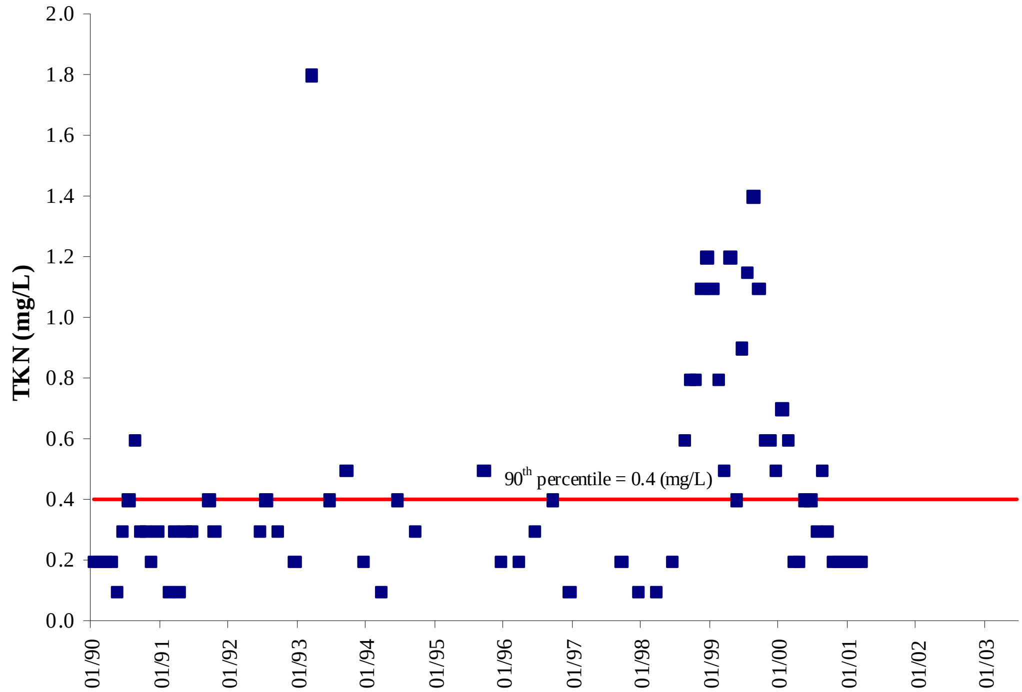

Figure 3.18 Total Kjeldahl nitrogen concentrations at VADEQ station 6CNFH080.43 on the Upper North Fork Holston River.

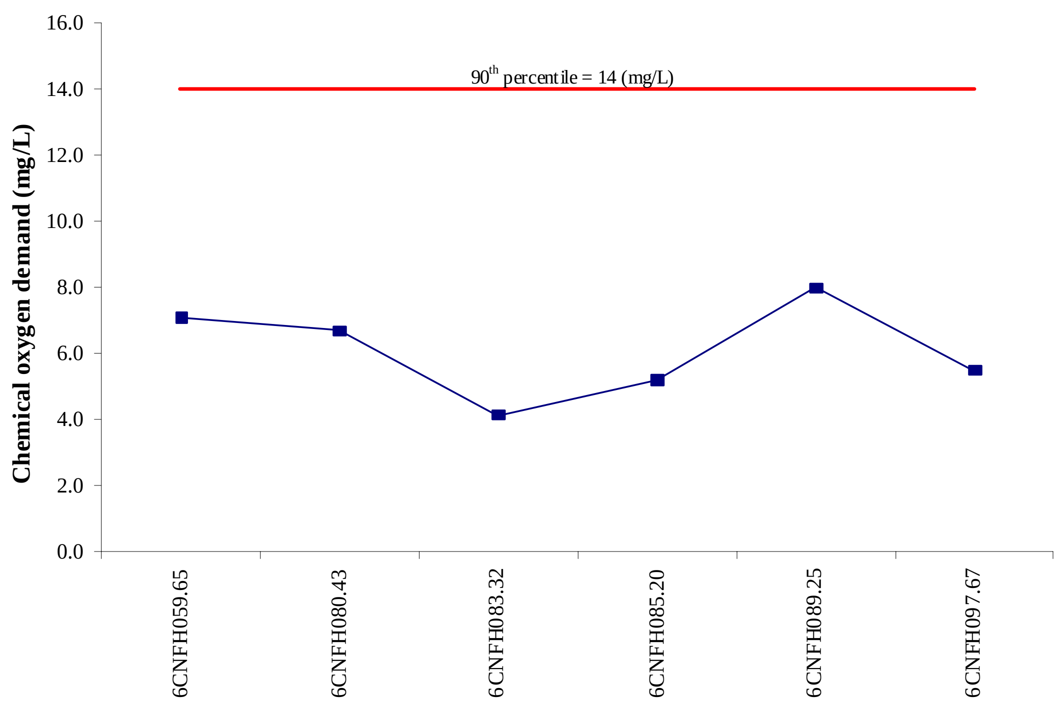

Figure 3.19 Median chemical oxygen demand concentrations at VADEQ stations on the upper portion of the North Fork Holston River.

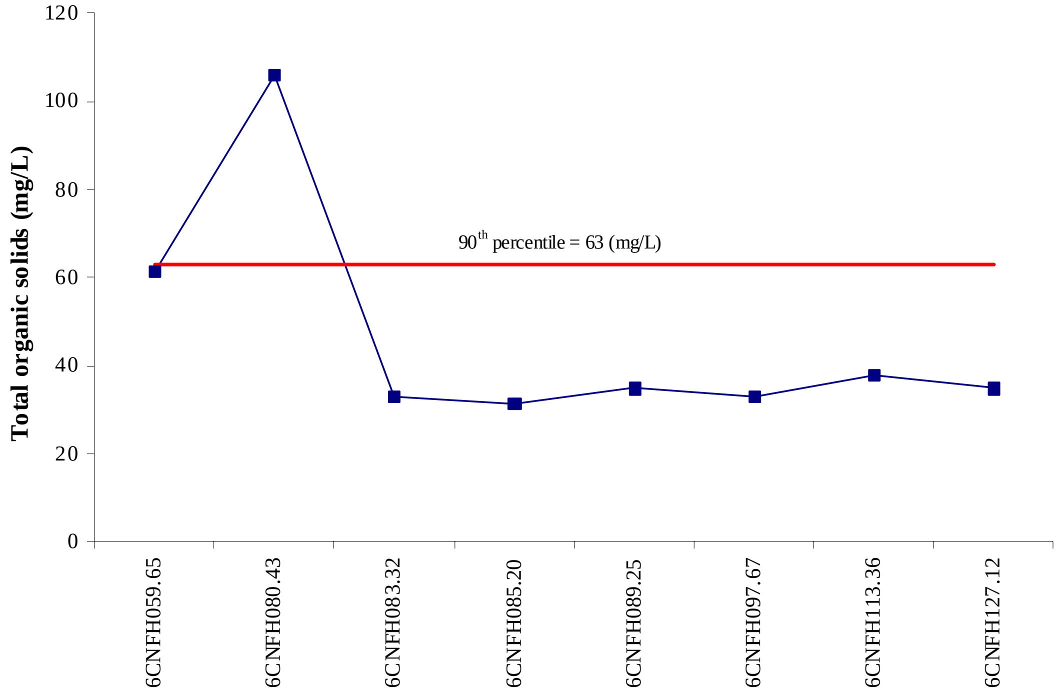

Figure 3.20 Median total organic solids demand concentrations at VADEQ stations on the upper portion of the North Fork Holston River.

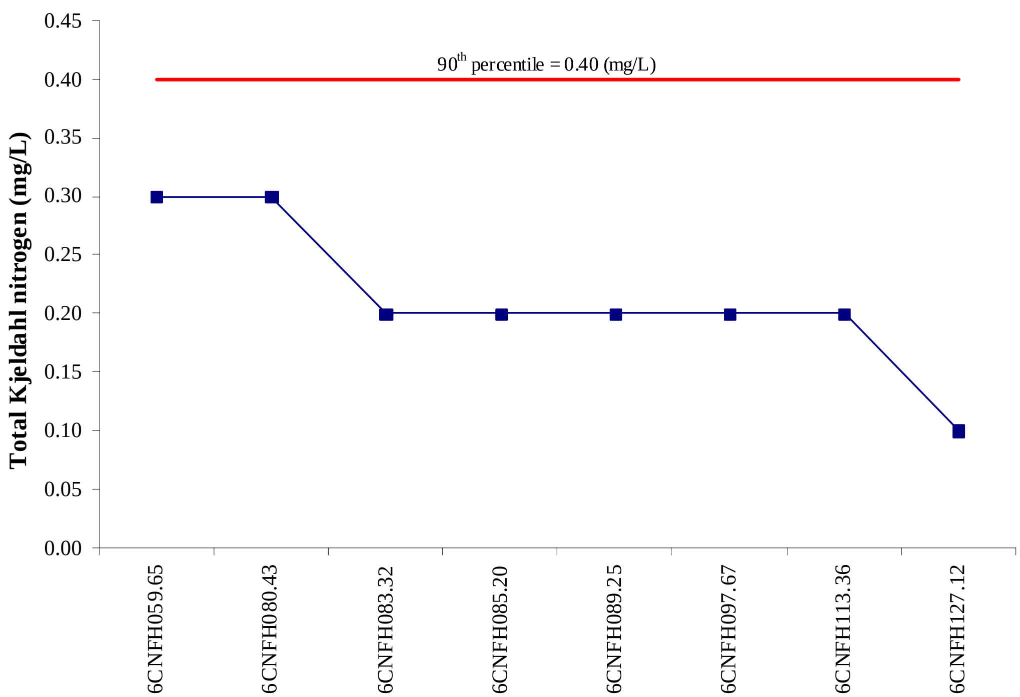

Figure 3.21 Median total Kjeldahl nitrogen concentrations at VADEQ stations on the upper portion of the North Fork Holston River.

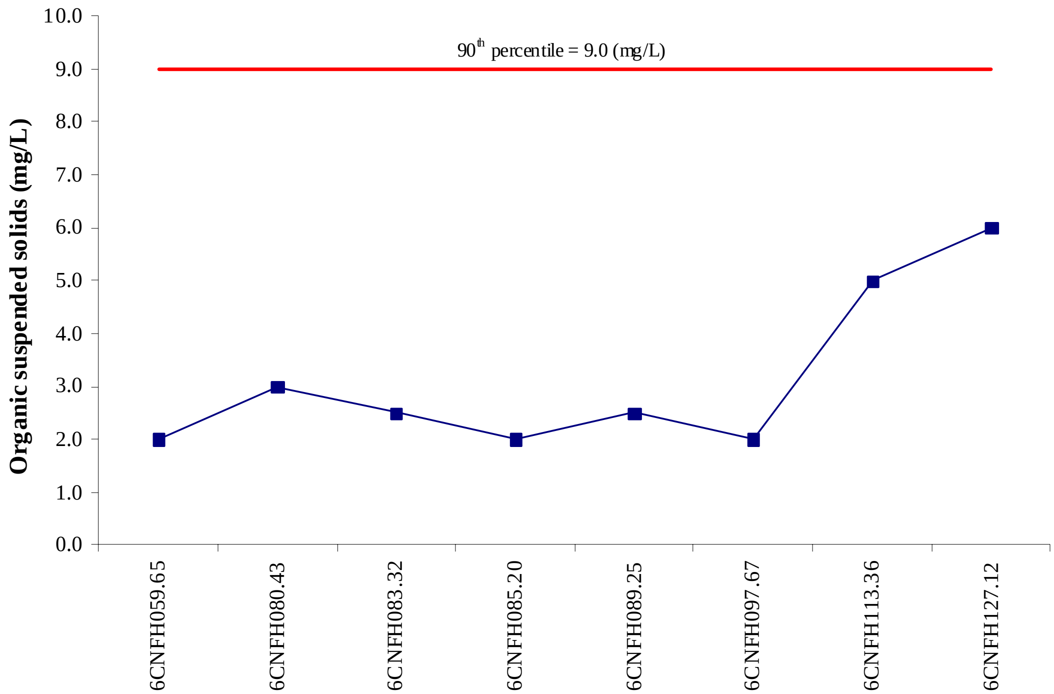

Figure 3.22 Median organic suspended solids concentrations at VADEQ stations on the upper portion of the North Fork Holston River.

3.4 Probable Stressors

Table 3.3 Probable stressors in the Upper North Fork Holston River.

Parameter	Location in Document
Conductivity (Chloride)	Section 3.4.1

3.4.1 Conductivity/Chloride

High conductivity values have been linked to poor benthic health (Pond, 2004). In the development of both the VASCI and the West Virginia Stream Condition Index, the reference streams used had conductivity levels that did not exceed 500 µmhos/cm. A comprehensive four-year study by the State of Kentucky's Department of Environmental Protection show that conductivities in excess of 500 µmhos/cm had a dramatic impact on sensitive mayflies. They theorized that the increase in salinity irritated mayfly gills and they had difficulty obtaining adequate oxygen. A conductivity value of 402 µmhos/cm, which represented the 90th percentile from 49 monitoring stations in Southwest Virginia, was used as a screening value in this analysis. Seventy-six percent of the conductivity measurements made at VADEQ monitoring station 6CNFH080.43 exceeded the screening value and there was a maximum value of 1,980 µmhos/cm. The median conductivity value at 6CNFH080.43 was 683 µmhos/cm and 26 values exceeded 1,000 µmhos/cm (Figure 3.23). This is in contrast to the VADEQ monitoring stations located near the benthic stations used as ecoregion reference stations, 6CNFH085.20 (median conductivity = 200 µmhos/cm) and 6CNFH097.67 (median conductivity = 245 µmhos/cm). In addition, VADEQ monitoring stations 6CNFH079.22 and 6CNFH081.69 had conductivity values that exceeded the comparison value in more than 10% of the measurements, 75% and 83%, respectively (Figures 3.24 and 3.25). Figure 3.26 shows median conductivity values for all of the monitoring stations in the upper portion of the North Fork Holston River. An examination of the benthic assemblage at VADEQ benthic monitoring station 6CNFH080.45 found that it consisted of less than 5% mayflies. The percent mayflies in the upstream benthic monitoring stations used as ecoregion reference stations were 38% (6CNFH085.31) and 23% (6CNFH098.47).

Both the EPA and the VADEQ consider chloride to be a toxic parameter and both have an acute and a chronic water quality standard criterion for it. The acute water quality standard of 860.0 mg/L is based on a one-hour average concentration that is not to be exceeded more than once every three years. The chronic water quality standard of 230 mg/L is based on a four-day average concentration not to be exceeded more than once every three years (9 VAC 25-260-140). Conductivity is a measure of the electrical potential of the dissolved ions that are present in a sample. Chloride is one of the ions present in the Upper North Fork Holston River and concentrations at the VADEQ ambient monitoring station 6CNFH080.43 far exceed the EPA and VADEQ water quality standard concentration of 230 mg/L (Figure 3.27). Twenty-six percent of the chloride concentrations reported at this monitoring station exceeded the chronic water quality standard and one concentration (951 mg/L in March 1993) exceeded the acute water quality standard of 860 mg/L. 6CNFH080.43 is located within the impaired segment at Saltville. Median chloride concentrations are shown in Figure 3.28.

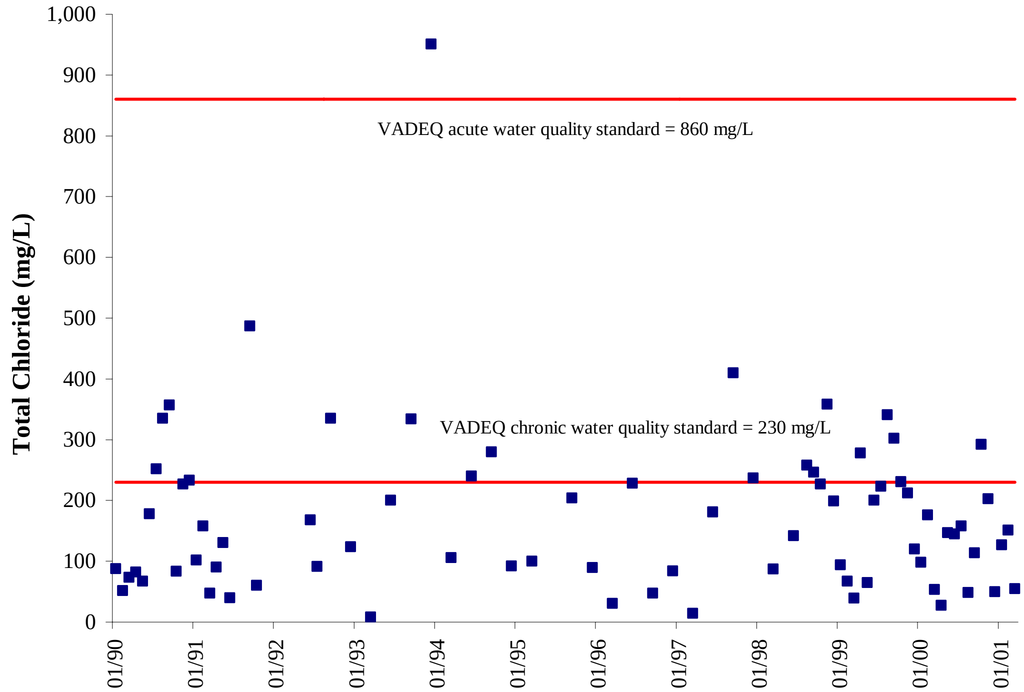

Figure 3.23 Conductivity values at VADEQ station 6CNFH080.43 on the Upper North Fork Holston River.

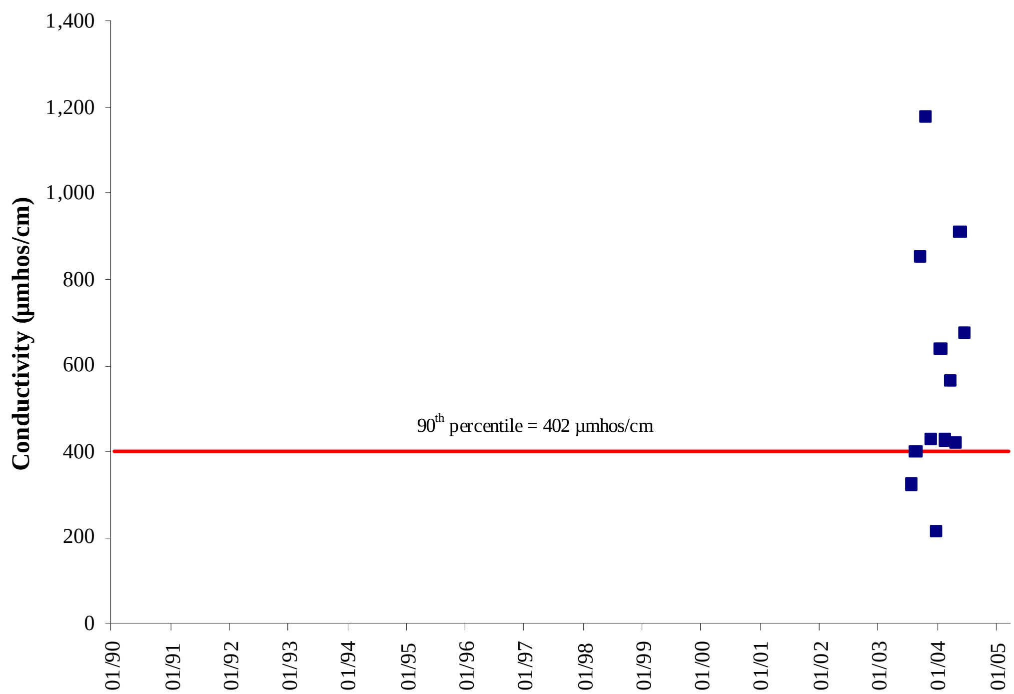

Figure 3.24 Conductivity values at VADEQ station 6CNFH079.22 on the Upper North Fork Holston River.

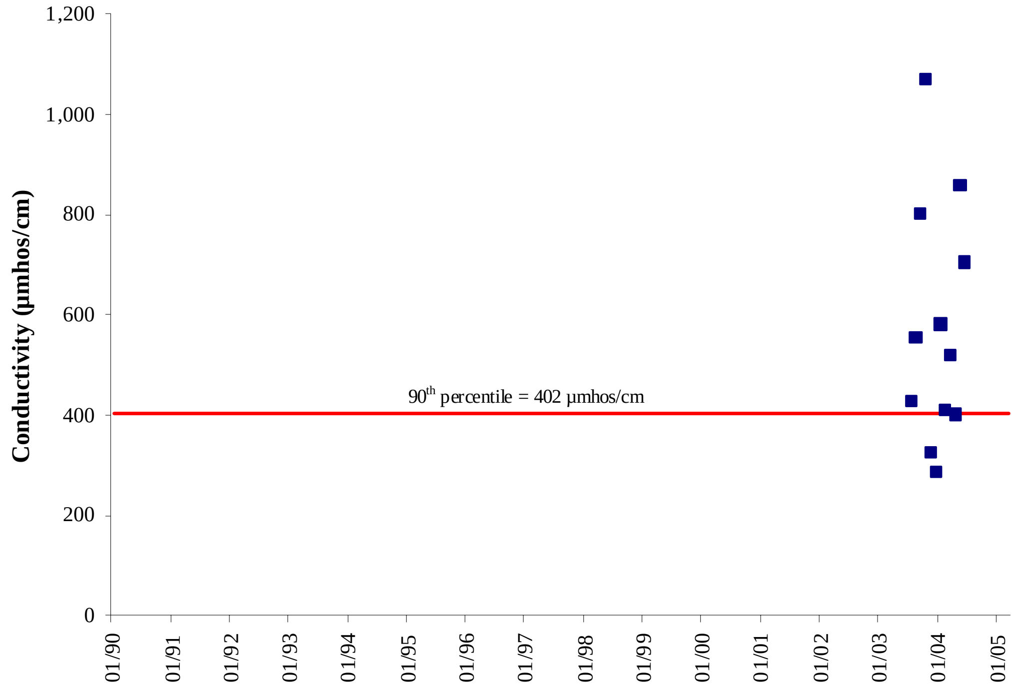

Figure 3.25 Conductivity values at VADEQ station 6CNFH081.69 on the Upper North Fork Holston River.

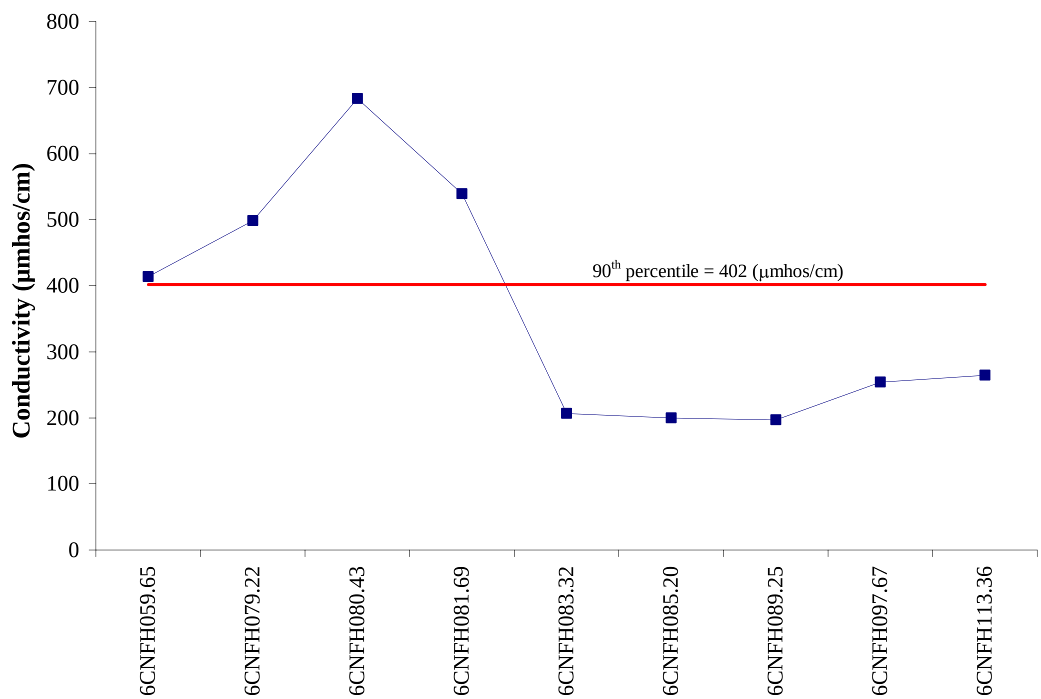

Figure 3.26 Median conductivity values at VADEQ stations on the upper portion of the North Fork Holston River.

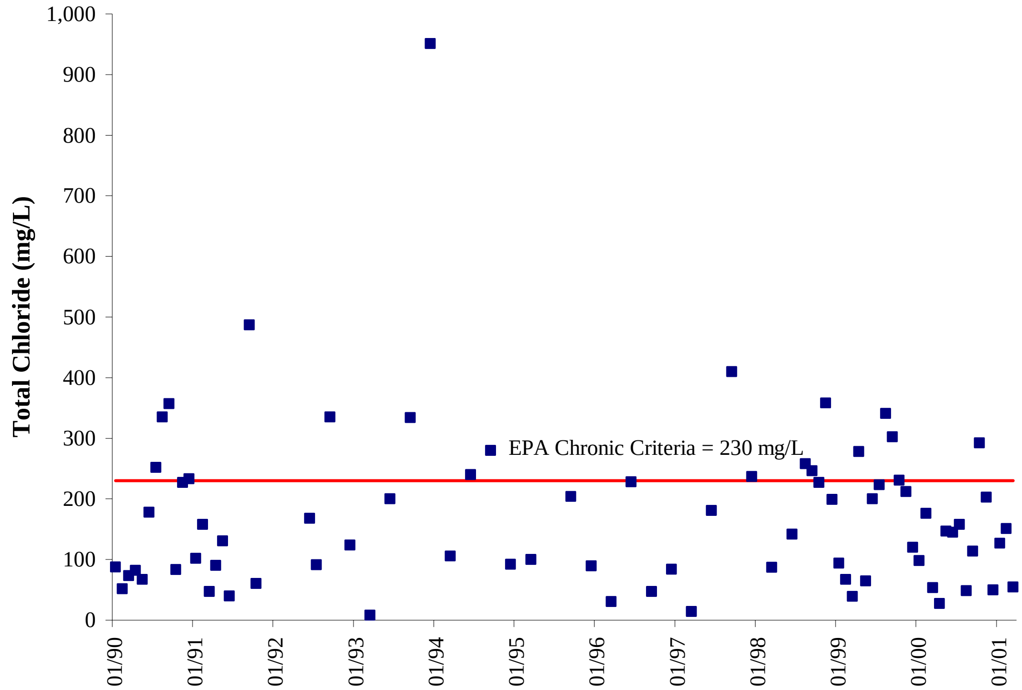

Figure 3.27 Chloride concentrations at VADEQ station 6CNFH080.43 on the Upper North Fork Holston River.

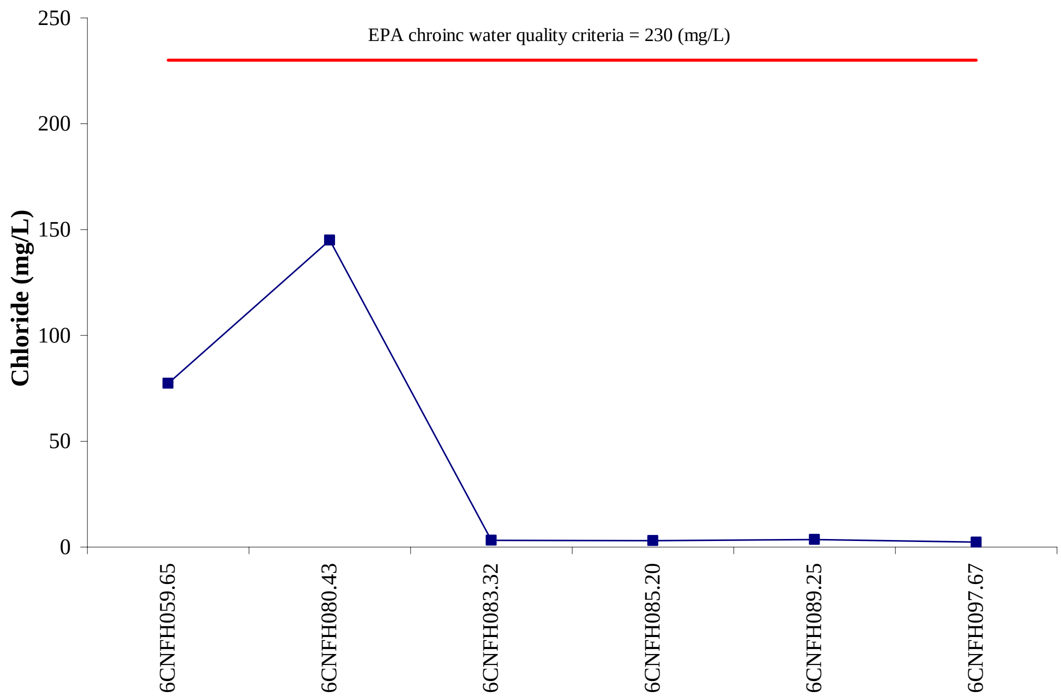

Figure 3.28 Median chloride concentrations at VADEQ monitoring stations on the upper portion of the North Fork Holston River.

Based on the persistently high chloride concentrations, many in excess of the chronic water quality standard and the single acute water quality standard violation, chloride will be the target pollutant used to address the benthic impairment in the Upper North Fork Holston River.

3.5 Trend and Seasonal Analyses

In order to improve the TMDL allocation scenarios and, therefore, the success of implementation strategies, trend and seasonal analyses were performed on water quality parameters that were identified as possible or probable stressors. A Seasonal Kendall Test was used to examine long-term trends. The Seasonal Kendall Test ignores seasonal cycles when looking for long-term trends. This improves the chances of finding existing trends in data that are likely to have seasonal patterns. Additionally, trends for specific seasons can be analyzed. For instance, the Seasonal Kendall Test can identify the trend (over many years) in dissolved oxygen levels during a particular season or month. A seasonal analysis of water chemistry results was conducted using the Mood's Median Test. This test was used to compare median values of water quality in each season.

The results of the Seasonal Kendall Test used to detect long-term trends are shown in Tables 3.4 - 3.6 for stations in the impaired segment that had enough data to use in the analysis. The results of the Mood's Median Test for seasonality for water quality data from the Upper North Fork Holston River are shown in Tables 3.7 – 3.10. Values in seasons with the same median group letter are not significantly different from each other at a 95% significance level. For example, if winter and spring are in median group "B", they are not significantly different from each other. The results generally indicated that there is a significant difference between high flow seasons (winter and spring) and low flow seasons (summer and fall). For chlorides this means that higher concentrations typically occur during the low flow months of summer and fall. If sufficient data was not available, trend and/or seasonality was not calculated.

Table 3.4 Trend Analysis results for water quality data at VADEQ monitoring station 6CNFH080.43 on Upper North Fork Holston River.

Water Quality Constituent	Trend
Chloride	No Trend
Conductivity	No Trend
Chemical oxygen demand	No Trend
Total organic solids	No Trend
Total Kjeldahl Nitrogen	No Trend

Table 3.5 Trend Analysis results for water quality data at VADEQ monitoring station 6CNFH085.20 on Upper North Fork Holston River.

Water Quality Constituent	Trend
Conductivity	-2.571

Table 3.6 Summary of Mood's Median Test on conductivity at station 6CNFH080.43.

Season	Mean (µmhos/cm)	Minimum (µmhos/cm)	Maximum (µmhos/cm)	Median Groups	
Winter	428.37	108.55	739.00	A	
Spring	661.68	195.33	1,058.60	A	
Summer	1,149.09	399.50	1,980.00		B
Fall	776.09	217.00	1,389.50	A	B

Table 3.7 Summary of Mood's Median Test on chloride at station 6CNFH080.43.

Season	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Median Groups	
Winter	82.22	7.80	176.00	A	
Spring	144.92	27.10	278.00	A	
Summer	253.83	47.10	487.00		B
Fall	214.37	49.50	951.00	A	B

Table 3.8 Summary of Mood's Median Test on total organic solids at station 6CNFH080.43.

Season	Mean	Minimum	Maximum	Median Groups[1]		
Winter	57.21	16.50	121.00	A		
Spring	107.47	33.50	250.00		B	
Summer	223.28	48.50	638.50			C
Fall	132.61	49.00	264.00		B	C

Table 3.9 Summary of Mood's Median Test on conductivity at station 6CNFH085.20.

Season	Mean (µmhos/cm)	Minimum (µmhos/cm)	Maximum (µmhos/cm)	Median Groups	
Winter	182.60	146.00	221.71	A	
Spring	174.34	111.00	240.00	A	
Summer	251.22	168.00	319.00		B
Fall	222.52	10.60	359.00	A	B

4. MODELING PROCEDURE: LINKING THE SOURCES TO THE ENDPOINT

Establishing the relationship between in-stream water quality and the source loadings is a critical component of TMDL development. It allows for the evaluation of management options that will achieve the desired water quality endpoint. In the development of a TMDL for the Upper North Fork Holston River watershed, the relationship was defined through computer modeling based on data collected throughout the watershed. Monitored flow and water quality data were then used to verify that the relationships developed through modeling were accurate. In this section, the selection of modeling tools, parameter development, calibration, and model application for chloride is discussed.

4.1 Modeling Framework Selection

The USGS Hydrologic Simulation Program - Fortran (HSPF) water quality model was selected as the modeling framework to simulate conditions existing at the time of impairment and to perform TMDL allocations. The HSPF model is a continuous simulation model that can account for NPS pollutants in runoff, as well as pollutants entering the flow channel from point sources. In establishing the existing and allocation conditions, seasonal variations in hydrology, climatic conditions, and watershed activities can be explicitly accounted for in the model. The use of HSPF allowed for consideration of seasonal aspects of precipitation patterns within the watershed.

The HSPF model simulates a watershed by dividing it up into a network of stream segments (referred to in the model as RCHRES), impervious land areas (IMPLND) and pervious land areas (PERLND). Each subwatershed contains a single RCHRES, modeled as an open channel, and numerous PERLNDs and IMPLNDs, which represent the various land uses in that subwatershed. Water and pollutants from the land segments in a given subwatershed flow into the RCHRES for that subwatershed. Point discharges and withdrawals of water and pollutants are simulated as flowing directly to or withdrawing from a particular RCHRES as well. Water and pollutants from a given RCHRES flow into the next downstream RCHRES. The network of RCHRESs is constructed to mirror the configuration of the stream segments found in the physical world. Therefore, activities simulated in one impaired stream segment affect the water quality downstream in the model.

4.2 Model Setup

The National Land Cover Data (NLCD) produced cooperatively between USGS and EPA was utilized for this study. The collaborative effort to produce this dataset is part of a Multi-Resolution Land Characteristics (MRLC) Consortium project led by four U.S. government agencies: EPA, USGS, the Department of the Interior National Biological Service (NBS), and NOAA.

Using 30-meter resolution Landsat 5 Thematic Mapper (TM) satellite images taken between 1990 and 1994, digital land use coverage was developed identifying up to 21 possible land use types. Classification, interpretation, and verification of the land cover dataset involved several data sources (when available) including: aerial photography, soils data (NRCS 2004a, NRCS, 2004b), population and housing density data, state or regional land cover data sets, USGS land use and land cover (LUDA) data, 3-arc-second Digital Terrain Elevation Data (DTED) and derived slope, aspect and shaded relief, and National Wetlands Inventory (NWI) data.

The land area of the Upper North Fork Holston River watershed is approximately 165,488 acres with forest and agriculture as the primary land uses (Table 4.1 and Figure 4.1). Approximate proportions of specific land uses are 74% forest, 24% agriculture, less than 1% urban, and 1.2% water.

Table 4.1 Land use and area of the Upper North Fork Holston River watershed.

Land use	Acreage
Water	1,915.7
Urban	1,315.4
Tailings Pond	103.2
Forest	122,408.1
Agricultural	39,590.5
Wetlands	154.8
Total	**165,487.7**

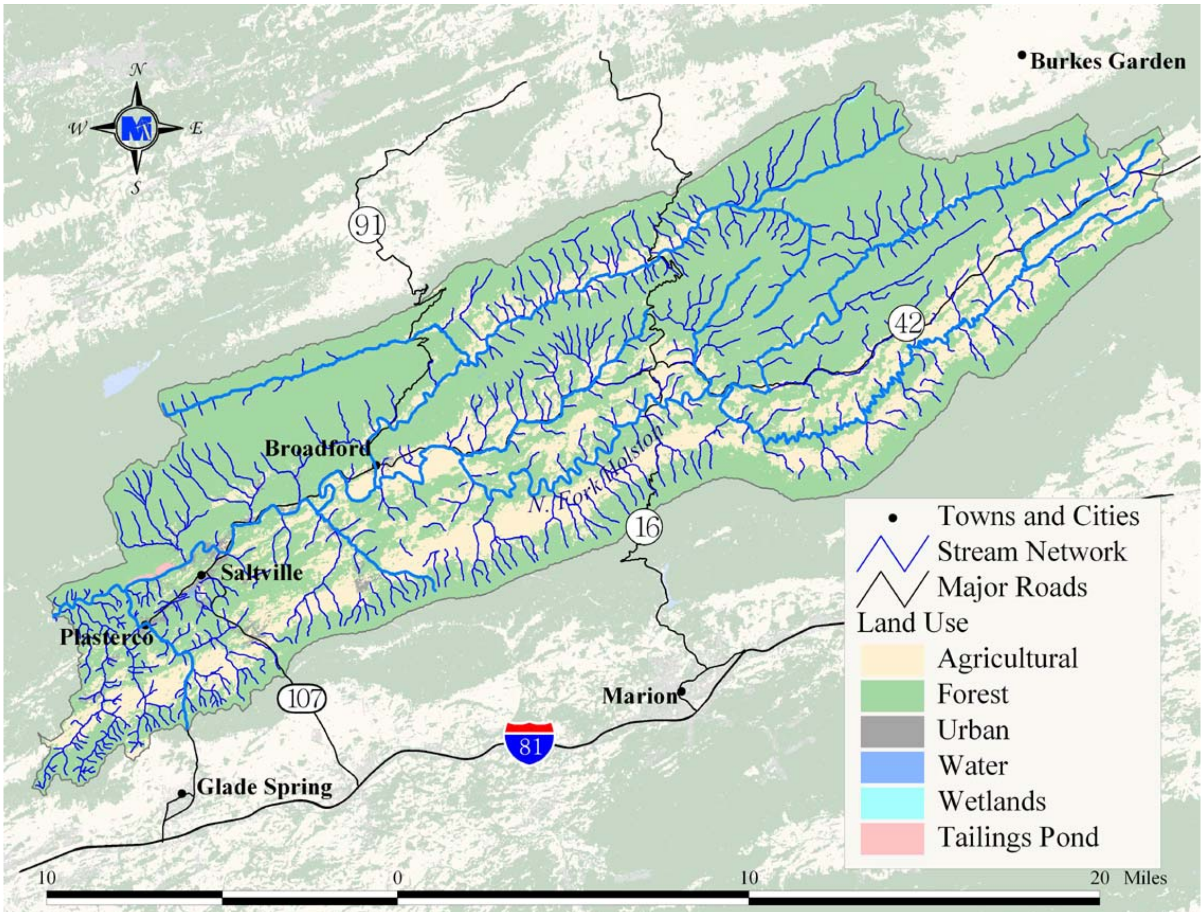

Figure 4.1 Land uses in the Upper North Fork Holston River watershed.

Using aerial photographs, NLCD, U.S. Census Bureau Topologically Integrated Geographic Encoding and Referencing (TIGER), and Virginia Department of Transportation (VDOT) road layers, possible land use types in the watershed were identified. The land use types were consolidated into 11 categories based on similarities in hydrologic features (Table 4.2). Within each subwatershed, up to the 11 land use categories were represented. Each land use has parameters associated with it that describe the hydrology of the area (*e.g.*, average slope length) and the behavior of pollutants. These land use types are represented in HSPF as PERLNDs and IMPLNDs. Impervious areas in the watershed are represented in five IMPLND types, while there are 11 PERLND types, each with parameters describing a particular land use (Table 4.2). Some IMPLND and PERLND parameters (*e.g.*, slope length) vary with the particular subwatershed in which they are located. Others vary with season (*e.g.*, upper zone storage) to account for plant growth, die-off, and removal.

Table 4.2 Land use categories for the Upper North Fork Holston River watershed.

TMDL Land use Categories	**Pervious / Impervious (Percentage)**	**Land use Classifications** (MRLC Class No. where applicable**)**
Commercial	Pervious (80%) Impervious (20%)	Commercial/Industrial/Transportation (23)
Crops	Pervious (100%)	Row Crops (82)
Forest	Pervious (100%)	Transitional (33) Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43)
Pasture	Pervious (100%)	Pasture/Hay (81)
Quarries	Pervious (70%) Impervious (30%)	Quarries/Strip Mines/Gravel Pits (32)
Residential	Pervious (80%) Impervious (20%)	Low Intensity Residential (21) High Intensity Residential (22) Urban/Recreational Grasses (85)
Roads with brine applied	Pervious (1%) Impervious (99%)	TIGER and VDOT* Unpaved
Roads with salt applied	Pervious (1%) Impervious (99%)	TIGER and VDOT* Paved
Tailings Pond	Pervious (100%)	Tailings Pond (NHD 43604)
Water	Pervious (100%)	Open Water (11) Connector (NHD 33400) Lake (NHD 39004) Intermittent Stream (NHD 46001) Perennial Stream (NHD 46004, 46006) Artificial Path (NHD 55800)
Wetlands	Pervious (100%)	Woody Wetlands (91) Emergent Herbaceous (92)

* VDOT – Virginia Department of Transportation

To adequately represent the spatial variation in the watershed, the drainage area of the Upper North Fork Holston River was divided into 20 subwatersheds (Figure 4.2). The rationale for choosing these subwatersheds was based on the availability of surface flow data and water quality data. Surface water flow data and water quality data (*e.g.*, pH, alkalinity, chloride, etc.) are available at specific locations throughout the watershed. Subwatershed outlets were chosen to coincide with these monitoring stations since output from the model can only be obtained at the modeled subwatershed outlets. The spatial division of the watershed allowed for a more refined representation of pollutant sources, and a more realistic description of hydrologic factors in the watershed.

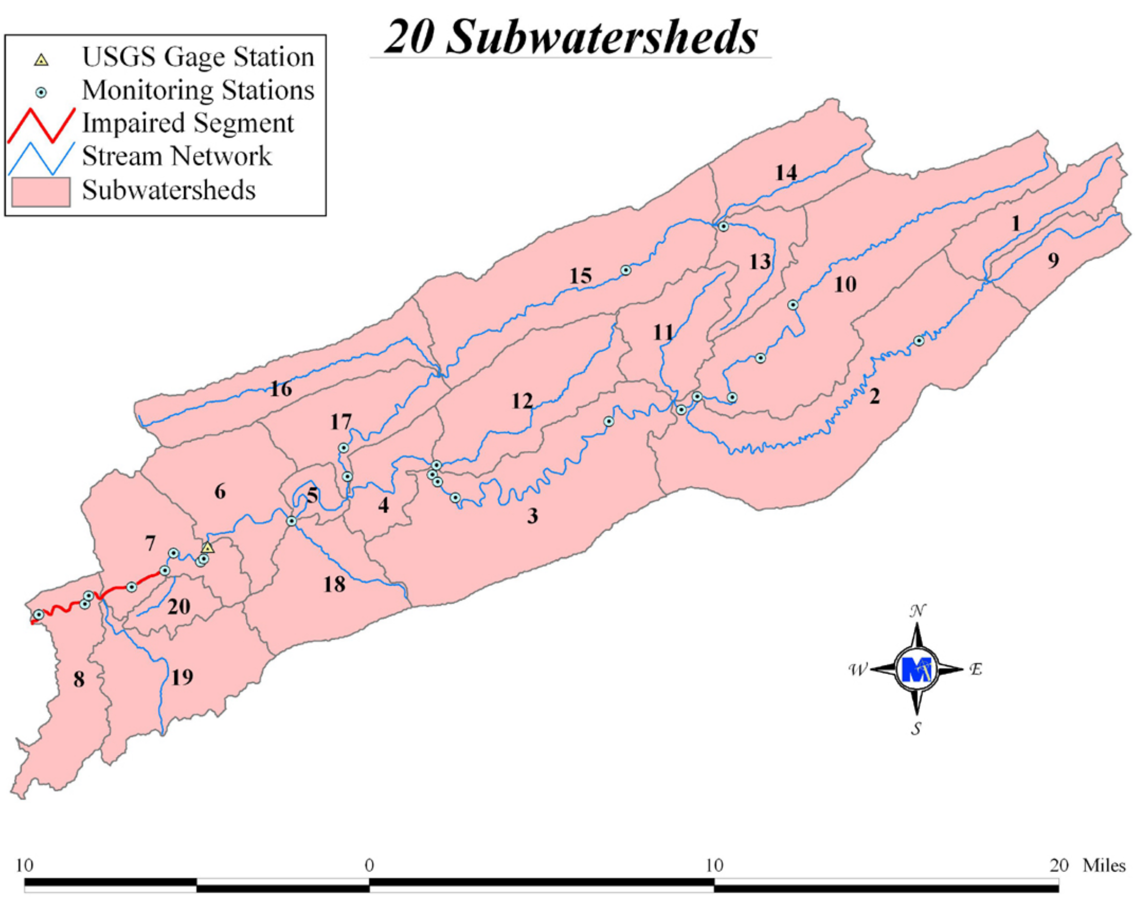

Figure 4.2 Subwatersheds delineated for modeling the Upper North Fork Holston River watershed.

4.3 Source Representation

Both point and nonpoint sources can be represented in the model. For the Upper North Fork Holston River, the surface runoff collected in the stormwater drainage system for the town of Saltville was modeled as a separate RCHRES. Nonpoint source contributions from the 11 land use categories were modeled as having three potential delivery pathways: delivery in surface runoff, delivery through interflow, and delivery through groundwater. Pollutants associated with interflow and/or groundwater were modeled by assigning a constant concentration for each in a particular PERLND. The HSPF model was used to link pollutants from nonpoint sources with downstream water quality. The pollutant modeled was the most probable benthic stressor, chloride, as identified in Chapter 3. Much of the data used to develop the model inputs for modeling water quality is time-dependent (*e.g.*, existence of control structures). Depending on the time frame of the simulation being run, the model was varied appropriately. Data representing the water quality calibration periods were used to develop the model used in this study.

4.3.1 VPDES Point Sources

Table 2.35 lists the VPDES point sources permitted to discharge into the Upper North Fork Holston River watershed during the time period modeled for this TMDL. There are six active VPDES point sources currently permitted to discharge into the Upper North Fork Holston River watershed. Flow from the discharges from PCS Phosphate (VA0070840) and U.S. Gypsum (VA0000876) were considered during the model calibration phase because both facilities were still in operation during this time but industrial operations have ceased at each facility. A design flow of 0.5 MGD was used for each facility. (While U.S. Gypsum's permit is listed as active, it expires on 3/12/2006 and it will not be reissued.)

Chloride wasteload allocations were developed for two single family home discharges. A chloride concentration of 50 mg/L (Metcalf & Eddy, 1991) and flow of 1,000 gallons per day was used for the model. An allocation was also developed for the Saltville Wastewater Treatment Plant (VA0026808). A chloride concentration for domestic sewage of 50 mg/L (Metcalf & Eddy, 1991) and a design flow of 0.50 MGD was used. The Saltville Gas Storage facility (VA0090115) has a permitted chloride concentration of 376 mg/L and design flow of 0.575 MGD.

4.3.2 Uncontrolled Discharges

Uncontrolled discharges were estimated using 1990 U.S. Census Bureau block demographics. Houses listed in the Census sewage disposal category "other means" were assumed to be disposing of sewage via uncontrolled discharges (253 housing units). Chloride loads from human waste for each discharge were estimated as 50 mg/L (Metcalf and Eddy, 1991). The chloride load from straight pipes was calculated by multiplying the flow of sewage per person per day by the population density of the subwatershed times the chloride concentration. This load was modeled as flowing directly to the stream network.

4.3.3 Failing Septic Systems

Failing septic systems were assumed to deliver all effluent to the soil surface where it was available for wash-off during a runoff event. In accordance with estimates from Raymond B. Reneau, Jr. of the Crop and Soil Environmental Sciences Department at Virginia Tech, a 40% failure rate for systems designed and installed prior to 1964, a 20% failure rate for systems designed and installed between 1964 and 1984, and a 5% failure rate on all systems designed and installed after 1984 was used in development of TMDL for the North Fork Holston River watershed (Reneau, 2000). Total septic systems in each category were calculated using U.S. Census Bureau block demographics. The applicable failure rate was multiplied by each total and summed to get the total failing septic systems per subwatershed. The chloride concentration for septic system effluent was multiplied by the average design load for the septic systems in the subwatershed to determine the total load from each failing system. Additionally, the loads were distributed seasonally based on a survey of septic pump-out contractors to account for more frequent failures during wet months. Chloride loads for failing septic systems were estimated as 50 mg/L (Metcalf and Eddy 1991).

4.3.4 Sewer System Overflows

Sewer system overflows from the Town of Saltville were modeled as flowing directly to the stream network. Chloride loads were estimated as 50 mg/L (Metcalf and Eddy 1991).

4.3.5 Road Salt Applications

Annual road salt application rates for Bland, Smyth, Tazewell and Washington counties were provided by the VDOT. The road salt applications were modeled as deposited on paved roads in the watershed on days with recorded snowfall. The daily rate was calculated using a ratio of snowfall that day to total snowfall during the modeling time period. This was done to simulate the practice of applying less salt for light snowfall and more salt during heavy snow events. These daily salt applications were used to estimate chloride in surface runoff from paved roads during months with recorded snowfall. The salt applications were modeled using an external time series depositing on the paved road IMPLNDs in the watershed.

4.3.6 Road Brine Applications

VDOT also applies brine to unpaved roads to control dust during dry periods in Smyth and Washington counties. It was assumed that the same amount of brine was applied after seven days with no rain. It was assumed that brine was applied from 8:00 am to 5:00 pm. These brine applications were used to estimate chloride in surface runoff from unpaved roads in the watershed during the drier months. The brine applications were modeled using an external time series depositing on the unpaved road IMPLNDs in the watershed.

4.4 Stream Characteristics

HSPF requires that each stream reach be represented by constant characteristics (*e.g.*, stream geometry and resistance to flow). In order to determine a representative stream profile for each stream reach, cross-sections were surveyed at locations that were representative of the stream for the modeled subwatersheds.

Most of the sections exhibited distinct flood plains with pitch and resistance to flow significantly different from that of the main channel slopes. The streambed, channel banks, and flood plains were identified. Once identified, the streambed width and slopes of channel banks and flood plains were calculated using the survey data. A representative stream profile for each surveyed cross-section was developed and consisted of a trapezoidal channel with pitch breaks at the beginning of the flood plain (Figure 4.3). With this approach, the flood plain can be represented differently from the streambed. To represent the entire reach, profile data collected at each end of the reach were averaged.

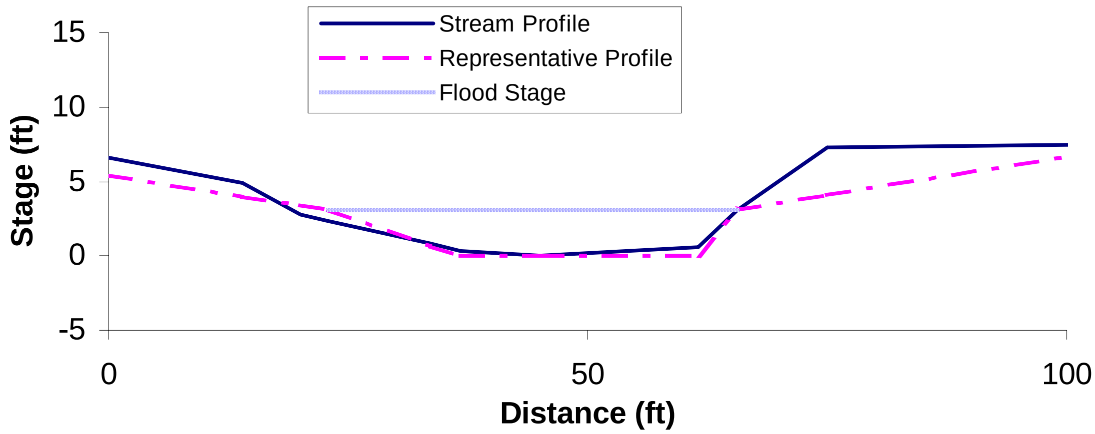

Figure 4.3 Stream profile representation in HSPF.

Conveyance was used to facilitate the calculation of discharge in the reach with different values for resistance to flow (*i.e.,* Manning's *n*) assigned to the flood plains and streambeds. The conveyance was calculated for each of the two flood plains and the main channel, and these figures were added together to obtain a total conveyance. Calculation of conveyance was performed following the procedure described by Chow (1959). The total conveyance was then multiplied by the square root of the average reach slope to obtain the discharge (ft^3/s) at a given depth.

A key parameter used in the calculation of conveyance is the Manning's roughness coefficient, *n*. There are many ways to estimate this parameter for a section. The method first introduced by Cowan (1956) and adopted by the Soil Conservation Service (1963) was used to estimate Manning's *n*. This procedure involves a 6-step process of evaluating the properties of the reach, which is explained in more detail by Chow (1959). Field data describing the channel bed, bank stability, vegetation, obstructions, and other pertinent parameters were collected. Photographs were also taken of the sections while in the field. Once the field data were collected, they were used to estimate the Manning's roughness coefficient for the section observed. The pictures were compared to pictures contained in Chow (1959) for validation of the estimates of the Manning's *n* for each section.

The result of the field inspections of the reach sections was a set of characteristic slopes (channel sides and field plains), bed widths, heights to flood plain, and Manning's roughness coefficients. Average reach slope and reach length were obtained from GIS layers of the watershed, which included elevation from DEMs and a stream-flow network digitized from USGS 7.5-minute quadrangle maps (scale 1:24,000). These data were used to derive the Hydraulic Function Tables (F-tables) used by the HSPF model (Table 4.3). The F-tables consist of four columns: depth (ft), area (ac), volume (ac-ft), and discharge (cfs). The depth represents the possible range of flow, with a maximum value beyond what would be expected for the reach. The area listed is the surface area of the stream reach or reservoir in acres. The volume corresponds to the total volume of the flow in the reach, and is reported in acre-feet. The discharge is simply the stream outflow, in cubic feet per second. The HSPF model calculates discharge based on volume of water in the reach.

Table 4.3 Example of an "F-table" calculated for the HSPF Model.

Depth (ft)	Area (ac)	Volume (ac-ft)	Discharge (cfs)
0.00	0.00	0.00	0.00
1.00	0.09	0.06	1.08
1.08	1.48	0.42	10.30
1.16	1.52	0.57	17.33
1.24	1.55	0.72	25.80
1.32	1.58	0.87	35.59
1.39	1.61	1.03	46.62
1.47	1.65	1.19	58.81
1.55	1.68	1.36	72.14
1.63	1.71	1.52	86.54
1.71	1.74	1.69	102.00
1.79	1.77	1.86	118.49
4.00	3.00	7.93	900.59
5.00	3.64	11.66	1413.26
7.00	4.90	21.02	2809.86
9.00	6.17	32.91	4836.44
18.00	11.87	117.80	25762.84

4.5 Selection of a TMDL Critical Condition.

EPA regulations at 40 CFR 130.7 (c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the Upper North Fork Holston River is protected during times when the waterbody is the most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and help in identifying the actions that may have to be undertaken to meet water quality standards. Chloride sources within the Upper North Fork Holston River watershed are attributed to both point and nonpoint sources. Critical conditions for waters impacted by surface runoff and interflow sources generally occur during periods of wet weather and high surface runoff. In contrast, critical conditions for groundwater-dominated systems generally occur during low flow and low dilution conditions.

A graphical analysis of chloride concentrations and flow duration interval from USGS station # 03488000 at Saltville showed that the critical flow levels are mid-range, dry, and low flows at station 6CNFH080.43 and mid-range at station 6CNFH085.20 (Figures 4.4 through 4.8). This indicates that there is a dominance of groundwater influence along with a lack of dilution from precipitation, surface runoff and interflow at these stations. The Upper North Fork Holston River exhibited no critical flow level at the other stations.

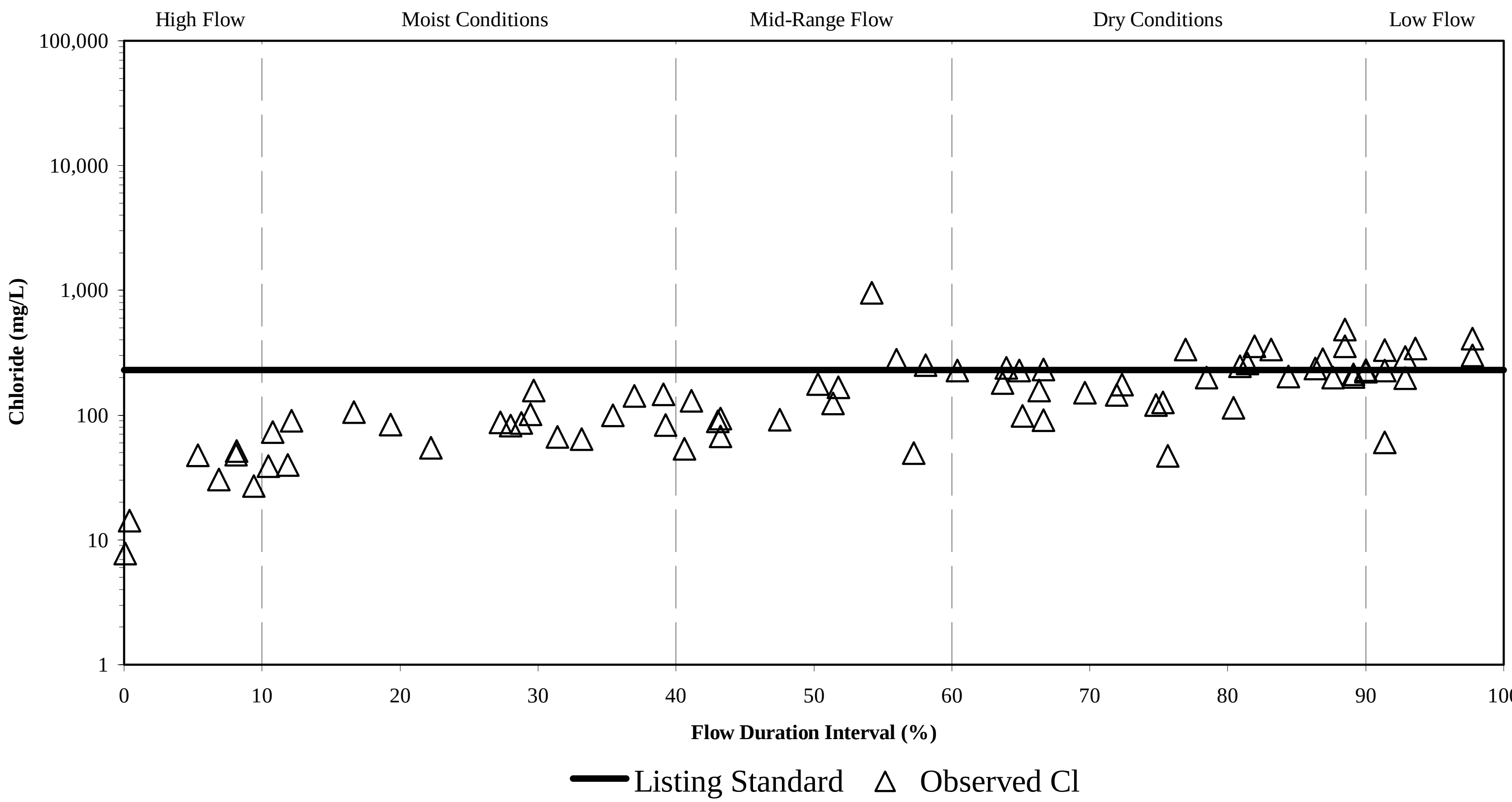

Figure 4.4 **Relationship between chloride concentrations (VADEQ station 6CNFH080.43) and discharge (USGS Station # 03488000) in the Upper North Fork Holston River.**

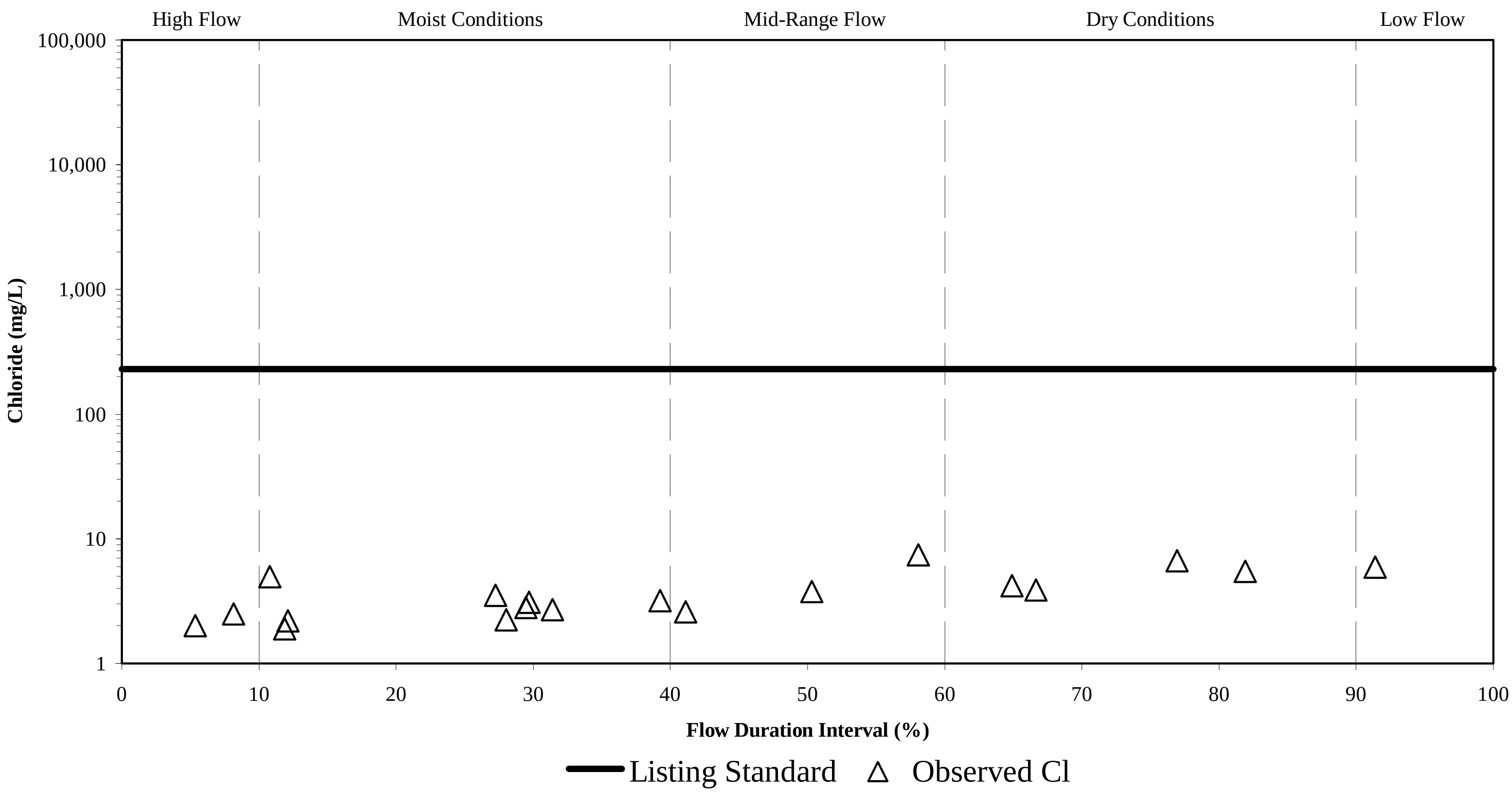

Figure 4.5 **Relationship between chloride concentrations (VADEQ station 6CNFH083.32) and discharge (USGS Station # 03488000) in the Upper North Fork Holston River.**

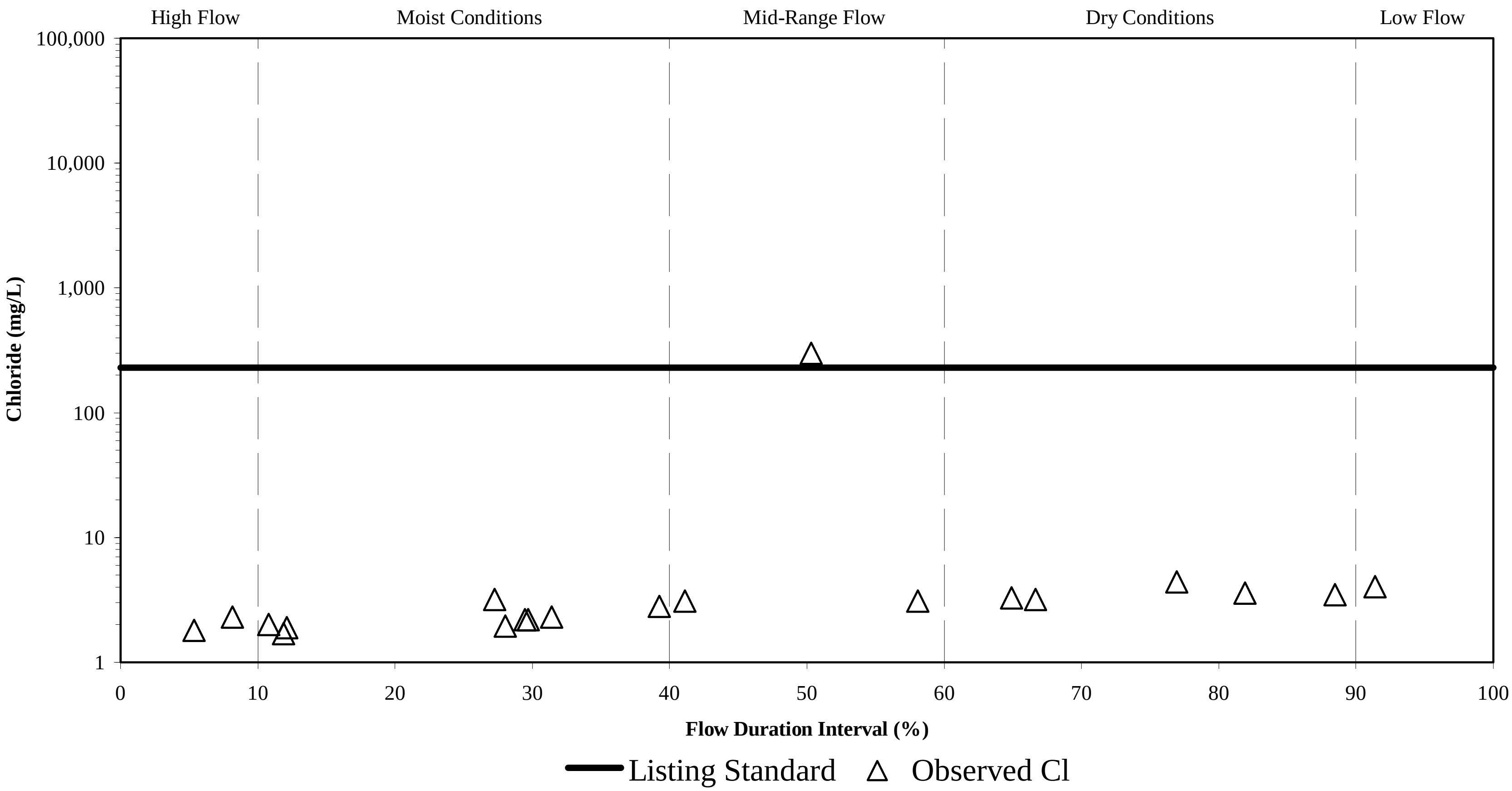

Figure 4.6 **Relationship between chloride concentrations (VADEQ station 6CNFH085.20) and discharge (USGS Station # 03488000) in the Upper North Fork Holston River.**

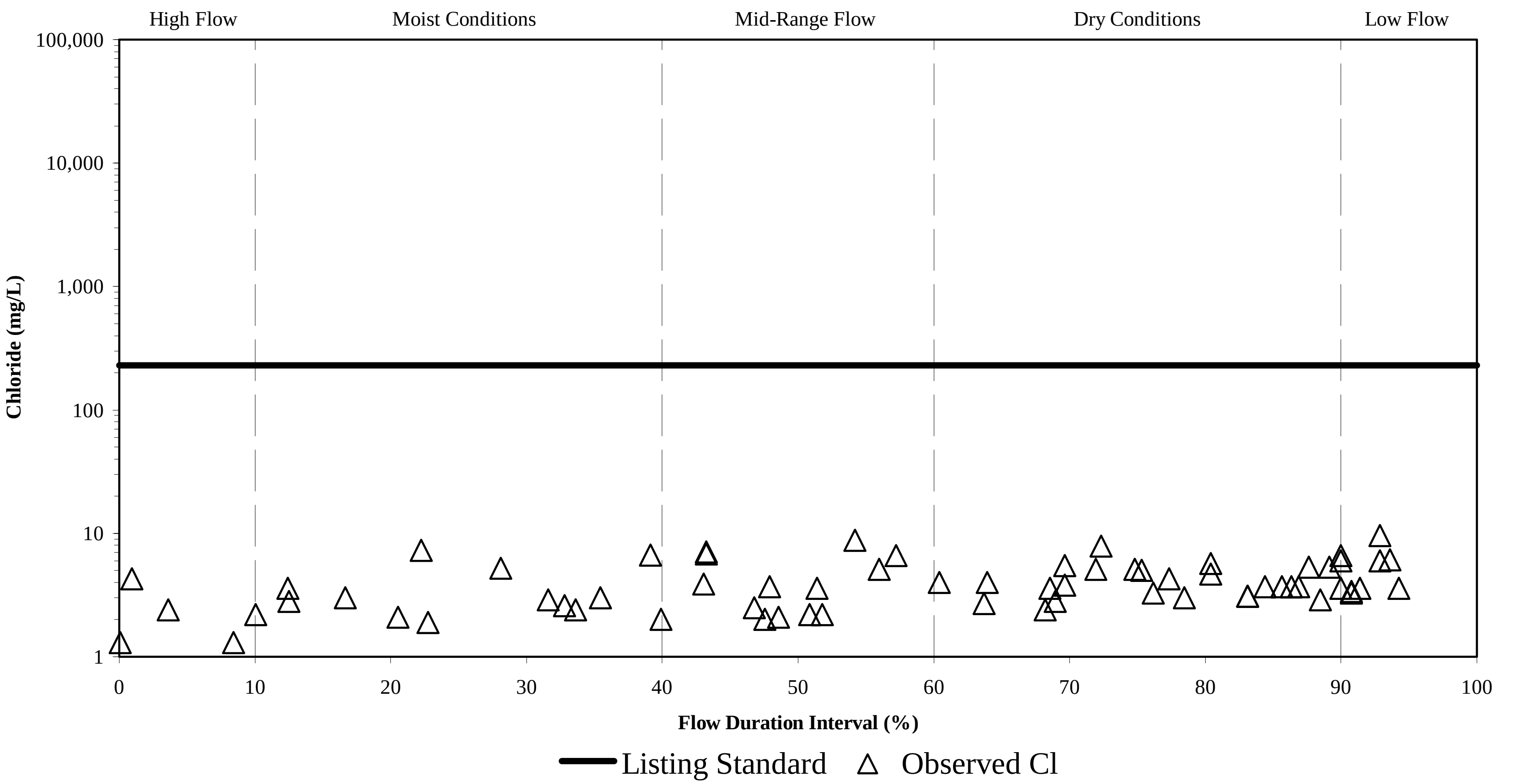

Figure 4.7 Relationship between chloride concentrations (VADEQ station 6CNFH089.25) and discharge (USGS Station # 03488000) in the Upper North Fork Holston River.

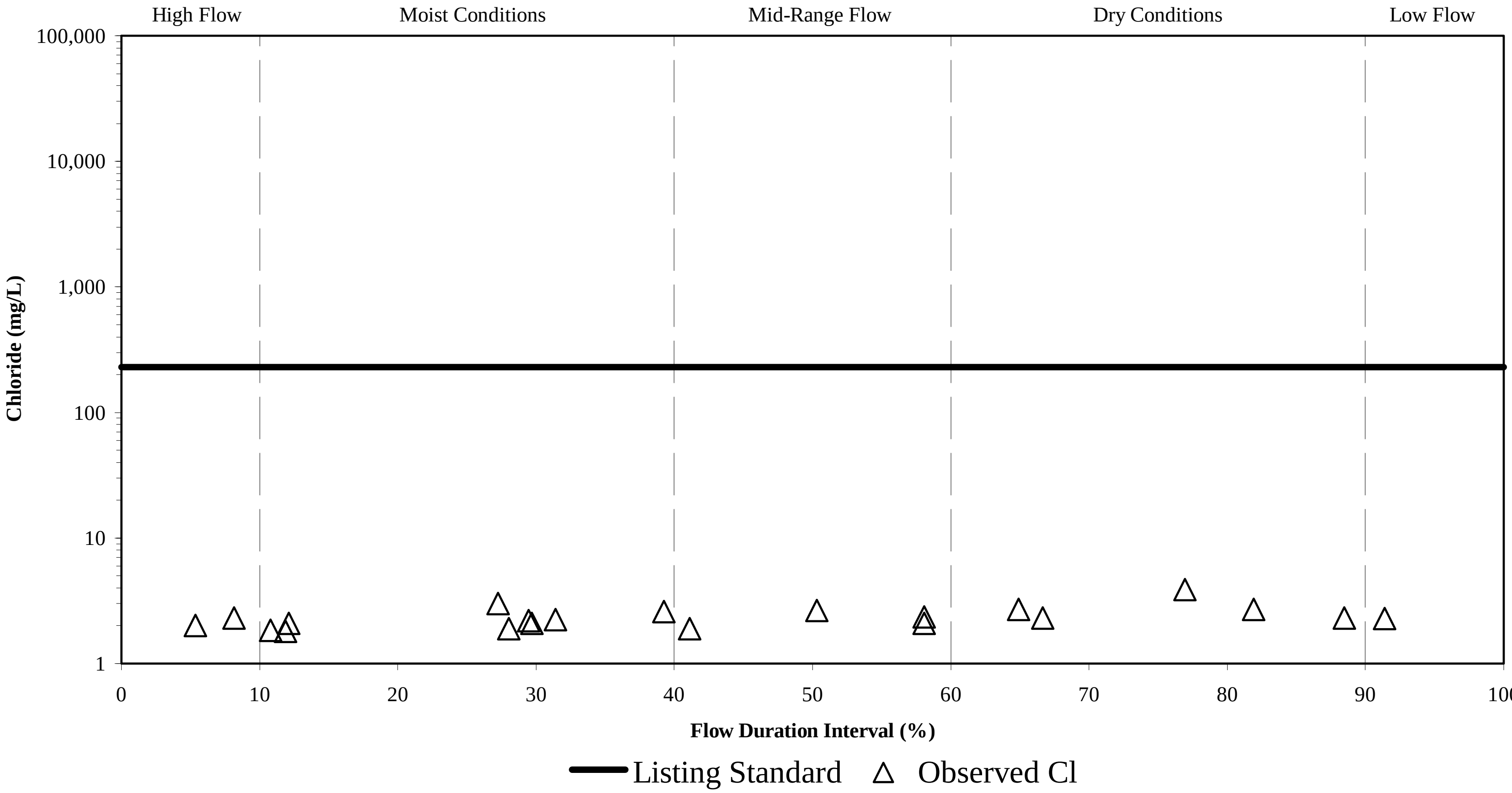

Figure 4.8 **Relationship between chloride concentrations (VADEQ station 6CNFH097.67) and discharge (USGS Station # 03488000) in the Upper North Fork Holston River.**

4.6 Selection of Representative Modeling Period

Selection of the modeling periods was based on two factors: availability of data (discharge and water-quality) and the need to model representative and critical hydrological conditions. Using these criteria, modeling periods were selected for hydrology and water quality calibration, hydrology and water quality validation, and modeling of allocation scenarios.

Flow data from USGS station # 03488000 were available during the period 6/1907 through 9/2003; water quality data were available from 1/1990 to 3/2001 at various locations throughout the watershed (Section 2.5.1).

In order to select a modeling period representative of the critical hydrological condition from the available data, the mean daily flow and precipitation for each season were calculated for the period 1923 through 2004. The National Climate Data Center (NCDC) cooperative station # 447506 located at Saltville, Virginia was used. There were some gaps in the data record and missing data was substituted with data from NCDC station # 441209 located at Burks Garden. This resulted in 81 observations of flow and 40-44 observations of precipitation for each season. The mean and variance of these observations were calculated. Next, a candidate period was chosen based on the availability of mean discharge data closest to the impairment assessment period. The representative period was chosen from this candidate period such that the mean and variance of each season in the modeled period was not significantly different from the historical data. The results of this analysis are shown in Figure 4.9, Figure 4.10 and Table 4.4. Therefore, the modeling periods were selected as representing the hydrologic regime of the watershed, accounting for critical conditions associated with all potential sources within the watershed. The resulting period for hydrologic calibration is 10/1/1995 through 9/30/2000. For hydrologic validation, the period selected was 10/1/1991 through 9/30/1995.

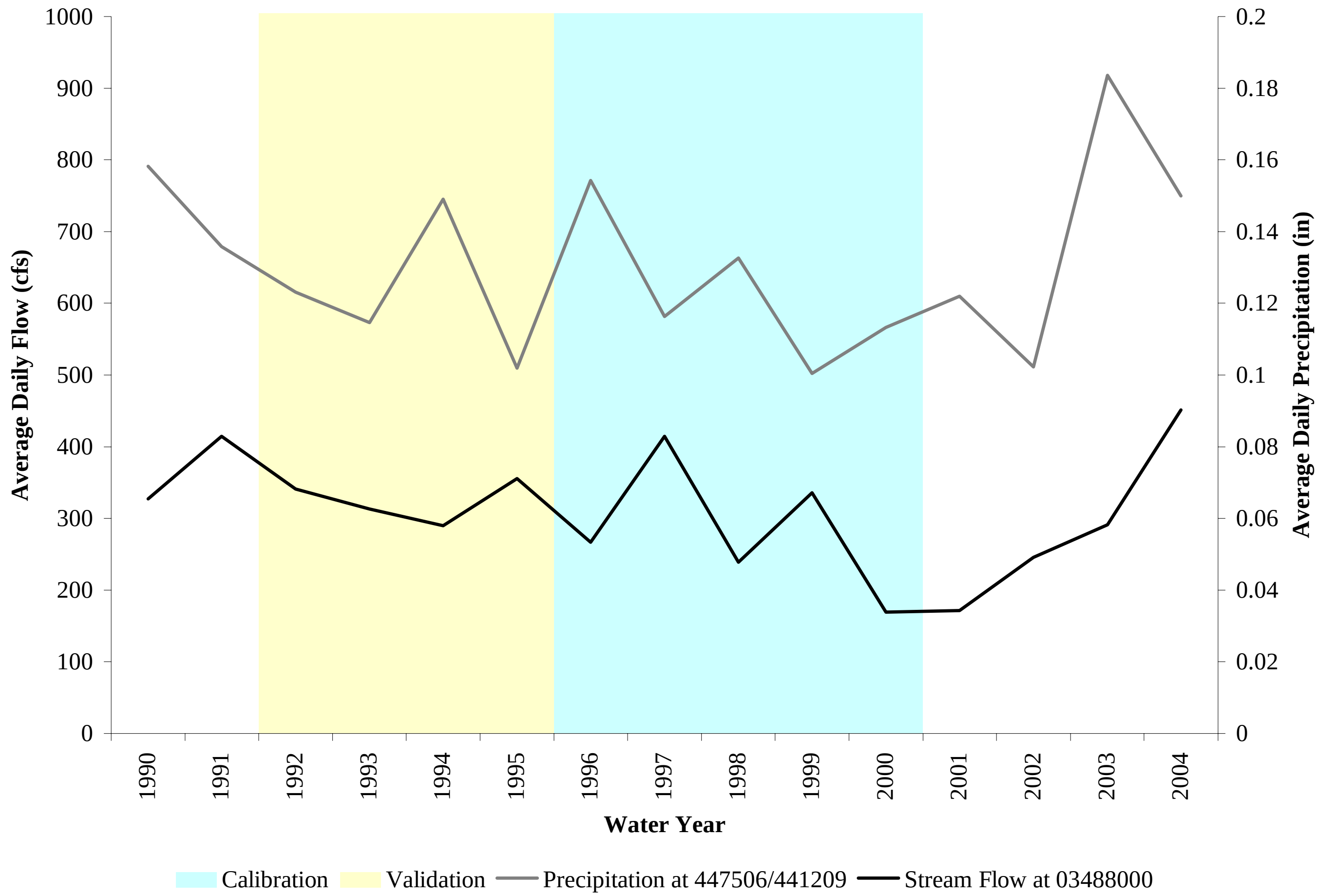

Figure 4.9 Annual historical flow (USGS Station # 03488000) and precipitation (Station 447506/441209) data.

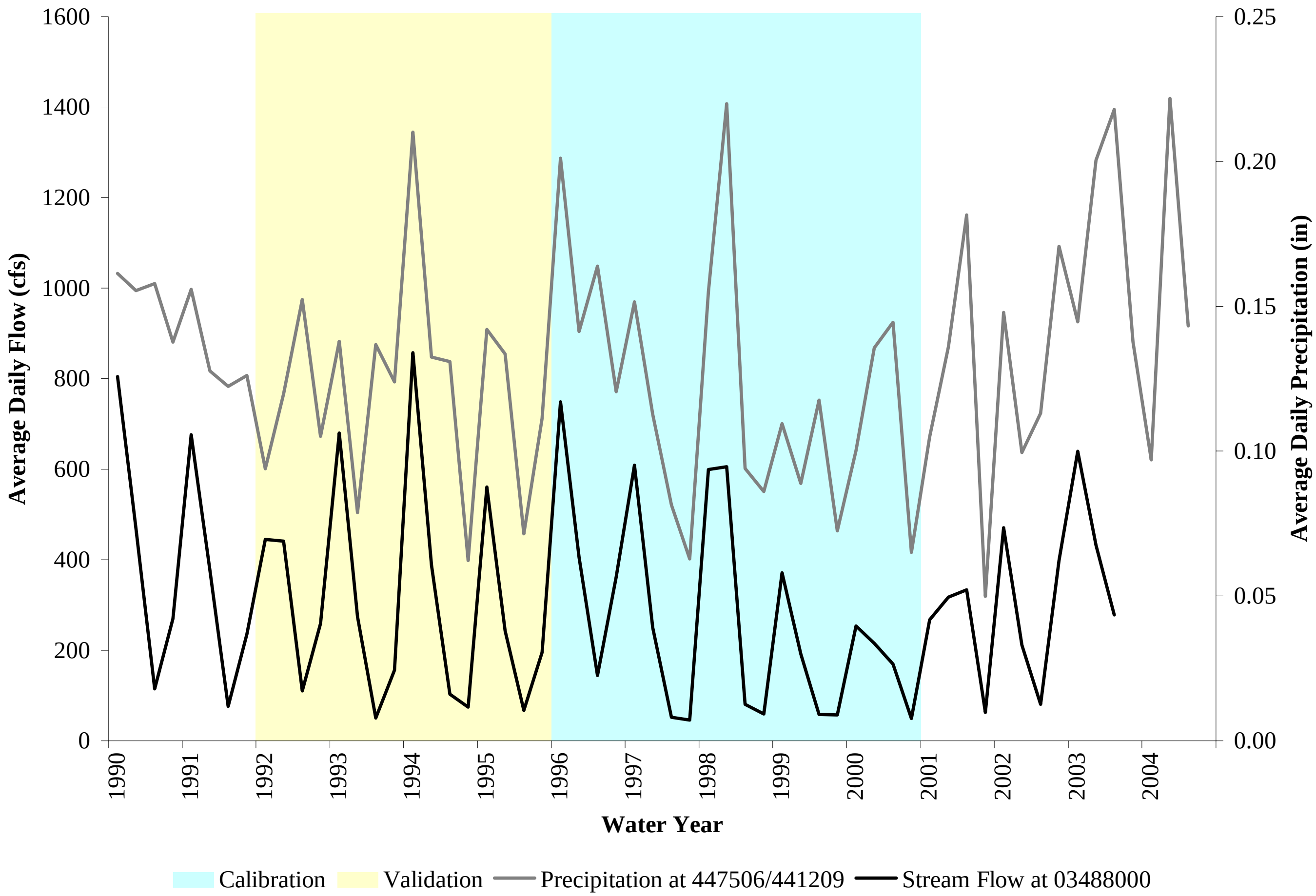

Figure 4.10 Seasonal historical flow (USGS Station # 03488000) and precipitation (Station 447506/441209) data.

Table 4.4 Comparison of hydrologic modeling period to historical records for the Upper North Fork Holston River.

	Streamflow (03488000)				Precipitation (447506/441209*)			
	Fall	Winter	Summer	Spring	Fall	Winter	Summer	Spring
	Historical Record (1923-2005)							
Mean	197	534	339	114	0.091	0.143	0.140	0.120
Variance	19436	36932	14363	5099	0.001	0.002	0.002	0.001
	Calibration & Validation Period (10/95 - 09/00, 10/91 - 9/95)							
Mean	173	609	350	83	0.100	0.150	0.128	0.119
Variance	12395	24607	18633	1112	0.001	0.002	0.002	0.001
	p-Values							
Mean	0.290	0.105	0.412	0.018	0.350	0.103	0.408	0.363
Variance	0.277	0.300	0.262	0.020	0.221	0.286	0.229	0.527

*Secondary Station utilized only when Primary Station was not in operation.

Chloride data for the Upper North Fork Holston River were available in the period from 1/1990 to 3/2001. The modeling period was selected to include portions of the VADEQ assessment periods that led to the inclusion of the North Fork Holston River on the 1996, 1998, 2002, and 2004 Section 303(d) lists. The chloride modeling periods were chosen as the same length of time as the hydrologic modeling periods with the maximum amount of observed data. The five years with the most chloride data (87 samples) were used as the calibration time period, 10/1/1990 through 9/30/1995. For chloride validation, the period selected was 10/1/1995 through 9/30/2000, during which 60 samples were collected.

4.7 Sensitivity Analysis

Sensitivity analyses were conducted to assess the sensitivity of the model to changes in hydrologic and water quality parameters as well as to assess the impact of unknown variability in source allocation.

Sensitivity analyses were run on both hydrologic and water quality parameters. The parameters adjusted for the hydrologic sensitivity analysis are presented in Table 4.5, with base values for the model runs given. The parameters were adjusted to -50%, -10%, 10%, and 50% of the base value (except where noted in Table 4.6), and the model was run for water years 1996 through 2000. Where an increase of 50% exceeded the maximum value for the parameter, the maximum value was used and the parameters that increased over the base value were reported. The hydrologic quantities of greatest interest in modeling NPS pollutants are those that govern peak flows and low flows. Peak flows, being a function of runoff, are important because they are directly related to the transport of NPS pollutants from the land surface to the stream. Peak flows were most sensitive to changes in the parameters governing infiltration (INFILT) and the groundwater recession rate (AGWRC). To a lesser extent, peak flows were sensitive to lower zone storage (LZSN) and upper zone storage (UZSN). Low flows are important in a water quality model because they control the level of dilution during dry periods. Parameters with the greatest influence on low flows (as evidenced by their influence in the Low Flows and Summer Flow Volume statistics) were AGWRC and INFILT and, to a lesser extent, lower zone evapotranspiration (LZETP). The responses of these and other hydrologic outputs are reported in Table 4.6.

Table 4.5 Base parameter values used to determine hydrologic model response.

Parameter	Description	Units	Base Value
AGWRC	Active Groundwater Coefficient	1/day	0.98
BASETP	Base Flow Evapotranspiration	---	0.01
CEPSC	Interception Storage Capacity	in	0.01-0.20
DEEPFR	Fraction of Deep Groundwater	---	0.01
INFILT	Soil Infiltration Capacity	in/hr	0.077-0.37
INTFW	Interflow Inflow	---	1.0
KVARY	Groundwater Recession Coefficient	1/day	0.0
LZSN	Lower Zone Nominal Storage	in	0.664-7.190
LZETP	Lower Zone Evapotranspiration	---	0.01-0.80
NSUR	Manning's *n* for Overland Flow	---	0.1
UZSN	Upper Zone Storage Capacity	in	0.670-2.464

Table 4.6 Sensitivity analysis results for hydrologic model parameters.

		(% Change)							
Model Parameter	**Parameter Change (%)**	**Total Flow**	**High Flows**	**Low Flows**	**Winter Flow Volume**	**Spring Flow Volume**	**Summer Flow Volume**	**Fall Flow Volume**	**Total Storm Volume**
AGWRC[1]	0.85	0.95	20.48	-40.25	10.47	-17.82	-19.35	27.94	25.64
AGWRC[1]	0.92	0.88	12.00	-26.17	9.99	-14.88	-16.82	21.26	21.71
AGWRC[1]	0.96	0.61	5.61	-13.91	7.53	-8.34	-11.08	9.30	13.29
AGWRC[1]	0.999	-24.39	-24.54	1.33	-32.93	-28.93	-7.86	-10.78	-31.36
BASETP	-50	0.29	-0.22	0.98	-0.05	0.81	0.88	-0.26	0.12
BASETP	-10	0.06	-0.04	0.20	-0.01	0.16	0.17	-0.05	0.04
BASETP	10	-0.06	0.04	-0.20	0.01	-0.16	-0.17	0.05	-0.03
BASETP	50	-0.29	0.23	-0.99	0.05	-0.80	-0.87	0.26	-0.01
DEEPFR	-50	0.38	0.21	0.51	0.32	0.40	0.49	0.42	0.36
DEEPFR	-10	0.08	0.04	0.10	0.06	0.08	0.10	0.08	0.07
DEEPFR	10	-0.08	-0.04	-0.10	-0.06	-0.08	-0.10	-0.08	-0.07
DEEPFR	50	-0.38	-0.21	-0.51	-0.32	-0.40	-0.49	-0.42	-0.36
INFILT	-50	-1.54	22.31	-20.38	6.53	-9.66	-12.46	2.00	3.29
INFILT	-10	-0.33	3.15	-2.91	1.04	-1.62	-2.16	0.11	0.18
INFILT	10	0.33	-2.70	2.52	-0.92	1.50	2.01	-0.05	-0.15
INFILT	50	1.65	-10.57	9.97	-3.60	6.53	8.72	0.10	0.06
INTFW	10	0.01	-0.22	-0.02	0.01	0.03	-0.01	-0.01	0.02
INTFW	50	0.04	-0.67	-0.11	0.07	0.09	-0.05	-0.05	0.07
INTFW	100	0.06	-0.83	-0.20	0.12	0.12	-0.08	-0.07	0.12
INTFW	200	0.08	-0.84	-0.31	0.18	0.16	-0.13	-0.07	0.17
LZSN	-50	5.15	12.69	2.98	8.74	-2.40	-0.99	14.62	2.88
LZSN	-10	0.82	2.02	0.46	1.50	-0.26	-0.45	2.16	0.67
LZSN	10	-0.74	-1.82	-0.37	-1.39	0.19	0.51	-1.85	-0.55
LZSN	50	-3.05	-7.63	-1.12	-6.08	0.51	2.81	-6.99	-3.55
CEPSC	-50	2.80	-2.52	8.08	-0.13	6.25	7.25	0.19	0.96
CEPSC	-10	0.45	-0.38	1.42	0.00	1.01	1.34	-0.18	0.07
CEPSC	10	-0.43	0.39	-1.38	0.00	-0.94	-1.32	0.20	-0.06
CEPSC	50	-1.97	2.22	-6.82	0.11	-4.24	-5.78	0.22	-0.15
LZETP	-50	8.87	6.32	17.59	5.45	1.64	17.99	21.04	-1.09
LZETP	-10	0.95	0.63	2.00	0.71	0.19	1.63	2.21	-0.03
LZETP	10	-0.75	-0.48	-1.59	-0.57	-0.16	-1.38	-1.60	-0.05
LZETP	50	-4.13	-2.35	-8.51	-2.47	-1.13	-9.97	-7.79	-0.30
MANNING	-50	0.07	0.45	-0.27	0.19	0.00	-0.14	0.06	0.12
MANNING	-10	0.01	0.09	-0.05	0.05	-0.01	-0.02	-0.03	0.02
MANNING	10	-0.01	-0.11	0.05	-0.05	0.03	0.03	-0.03	-0.02
MANNING	50	-0.05	-0.40	0.17	-0.11	0.03	0.08	-0.13	-0.07
UZSN	-50	3.74	8.91	-0.25	6.12	-0.48	0.89	7.54	5.99
UZSN	-10	0.61	1.44	-0.09	1.15	-0.08	-0.02	0.98	1.00
UZSN	10	-0.57	-1.35	0.12	-1.16	0.09	0.09	-0.77	-0.95
UZSN	50	-2.41	-5.92	0.91	-5.29	0.27	0.77	-2.61	-4.36

[1]Numbers represent actual values used for variable -- base value = 0.98.

For the water quality sensitivity analysis, an initial base run was performed using precipitation data from water years 1990 through 1995. The parameters adjusted for the water quality sensitivity analysis are presented in Table 4.7, with base values for the model runs given. The three parameters impacting the model's water quality response were increased and decreased by amounts that were consistent with the range of values for the parameter (Table 4.8).

Table 4.7 Base parameter values used to determine water quality model response.

Parameter	Description	Units	Base Value
MON-IFLW-CONC	Chloride in interflow	mg/ft^3	100
MON-GRND-CONC	Chloride in groundwater flow	mg/ft^3	100
WSQOP	Washoff Rate for chloride on land surface	in/hr	1

Table 4.8 Percent change in average monthly chloride (mg/L) for the years 1990 - 1995.

Model Parameter	Parameter Change (%)	Percent Change in Average Monthly Chloride for 1990-1995											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
MON-IFLW-CONC	-50	-6.05	-6.30	-10.13	-4.11	-6.51	-2.78	-1.58	-2.16	-2.25	-3.49	-5.14	-9.46
MON-IFLW-CONC	-10	-1.21	-1.26	-2.03	-0.82	-1.30	-0.56	-0.32	-0.43	-0.45	-0.70	-1.03	-1.89
MON-IFLW-CONC	10	1.21	1.26	2.03	0.82	1.30	0.56	0.32	0.43	0.45	0.70	1.03	1.89
MON-IFLW-CONC	50	6.05	6.30	10.13	4.11	6.51	2.78	1.58	2.16	2.25	3.49	5.14	9.46
MON-GRND-CONC	-50	-24.94	-30.50	-27.38	-30.36	-40.61	-46.76	-47.96	-47.56	-46.07	-45.49	-43.55	-31.69
MON-GRND-CONC	-10	-4.99	-6.10	-5.48	-6.07	-8.12	-9.35	-9.59	-9.51	-9.21	-9.10	-8.71	-6.34
MON-GRND-CONC	10	4.99	6.10	5.48	6.07	8.12	9.35	9.59	9.51	9.21	9.10	8.71	6.34
MON-GRND-CONC	50	24.94	30.50	27.38	30.36	40.61	46.76	47.96	47.56	46.07	45.49	43.55	31.69
WSQOP	-50	0.53	1.50	1.88	0.40	-2.48	-0.06	0.17	-0.02	0.21	0.45	0.19	6.01
WSQOP	-10	0.22	0.10	0.30	0.14	-0.62	-0.01	0.02	0.00	0.03	0.07	0.04	0.94
WSQOP	10	-0.25	-0.05	-0.26	-0.17	0.66	0.02	-0.02	0.00	-0.03	-0.06	-0.04	-0.84
WSQOP	50	-1.46	0.03	-1.06	-1.00	3.43	0.11	-0.05	-0.02	-0.12	-0.24	-0.17	-3.49

4.8 Model Calibration and Validation Processes

Calibration is performed in order to ensure that the model accurately represents the hydrologic and water quality processes in the watershed. The model's hydrologic parameters were set based on available climatic, soils, land use, and topographic data. Through calibration, these parameters were adjusted within appropriate ranges until the model performance was deemed acceptable.

Calibration is the process of comparing modeled data to observed data and making appropriate adjustments to model parameters to minimize the errors between observed and simulated events. Using observed data that is reported at a shorter time-step improves this process and, subsequently, the performance of a time-dependent model.

4.8.1 Hydrologic Calibration and Validation

Parameters that were adjusted during the hydrologic calibration represented the amount of evapotranspiration from the root zone (MON-LZETP), the recession rates for groundwater (AGWRC), the amount of soil moisture storage in the upper zone (MON-UZSN) and lower zone (MON-LZSN), the infiltration capacity (INFILT), baseflow PET (potential evapotranspiration -- BASETP), direct ET from shallow groundwater (AGWETP), Manning's *n* for overland flow plane (MON-MAN), interception storage capacity (CEPSC), fraction of deep groundwater (DEEPFR), interflow inflow (INTFW), variable groundwater recession (KVARY), and direct ET from shallow groundwater (AGWETP). Although HSPF is not a physically-based model and, thus, parameters are adjusted during calibration in order to match observed data, guidelines are provided by the EPA as to typically encountered values.

The Upper North Fork Holston River model was calibrated for hydrologic accuracy using daily continuous stream flow data at USGS Station # 03488000 and precipitation data at NCDC # 447506 both located at Saltville, Virginia. The results of hydrology calibration are presented in Tables 4.9 and 4.10 and in Figures 4.11 through 4.14. Table 4.11 shows the percent difference (or error) between observed and modeled data for total in-stream flows (-9.47%), upper 10% flows (1.04%), and lower 50% flows (9.30%) during model calibration. These values represent a close agreement with the observed data, indicating a well-calibrated model.

Table 4.9 Hydrology calibration criteria and model performance for the Upper North Fork Holston River (subwatershed 6) for the period 10/01/1995 through 9/30/2000.

	Observed	**Modeled**	**Error**
Total In-stream Flow:	84.14	76.17	-9.47%
Upper 10% Flow Values:	36.01	36.39	1.04%
Lower 50% Flow Values:	9.85	10.76	9.30%
Winter Flow Volume	39.58	36.29	-8.30%
Spring Flow Volume	25.57	20.00	-21.77%
Summer Flow Volume	7.84	8.37	6.76%
Fall Flow Volume	11.15	11.50	3.15%
Total Storm Volume	75.54	69.11	-8.52%
Winter Storm Volume	37.45	34.54	-7.76%
Spring Storm Volume	23.42	18.24	-22.13%
Summer Storm Volume	5.69	6.59	15.84%
Fall Storm Volume	8.98	9.74	8.39%

Table 4.10 contains the typical range for the hydrologic parameters along with the initial estimates and final calibrated values for the Upper North Fork Holston River. The final calibrated values for LSUR, SLSUR, AGWETP, and LZETP were outside of typical values, however, all values fell in the possible ranges (EPA, 2000a). The distribution of flow volume in the calibrated model between groundwater, interflow, and surface runoff at subwatershed 6 was 81.7%, 10.3%, and 8%, respectively.

Table 4.10 Model parameters utilized for hydrologic calibration of the Upper North Fork Holston River watershed and final calibrated values.

Parameter	Units	Typical Range of Parameter Value	Initial Parameter Estimate	Calibrated Parameter Value
FOREST	---	0.0 – 0.95	1.0	1.0
LZSN	In	2.0 – 15.0	6.70 – 15.05	2.75 – 6.17
INFILT	in/hr	0.001 – 0.50	0.0846 – 0.202	0.0338 – 0.0808
LSUR	Ft	100 – 700	46.1 – 700	46.1 – 700
SLSUR	---	0.001 – 0.30	0.0405 – 0.809	0.0405 – 0.809
KVARY	1/in	0.0 – 5.0	0.0	0.21
AGWRC	1/day	0.85 – 0.999	0.980	0.983
PETMAX	deg F	32.0 – 48.0	40.0	40.0
PETMIN	deg F	30.0 – 40.0	35.0	35.0
INFEXP	---	1.0 – 3.0	2.0	2.0
INFILD	---	1.0 – 3.0	2.0	2.0
DEEPFR	---	0.0 – 0.50	0.010	0.02 – 0.21
BASETP	---	0.0 – 0.20	0.010	0.019
AGWETP	---	0.0 – 0.20	0.0	0.0 – 0.70
INTFW	---	1.0 – 10.0	1.0	1.0
IRC	1/day	0.30 – 0.85	0.50	0.375
MON-INTERCEP	in	0.01 - 0.40	0.01 – 0.20	0.01 – 0.38
MON-UZSN	in	0.05 – 2.0	0.29 – 1.50	0.29 – 2.0
MON-LZETP	---	0.10 – 0.90	0.01 – 0.80	0.01 – 0.90
MON-MANNING	---	0.05 – 0.50	0.04 – 0.10	0.05 – 0.37
RETSC	in	0.01 – 0.30	0.10	0.10
KS	---	0.0 – 0.99	0.50	0.50

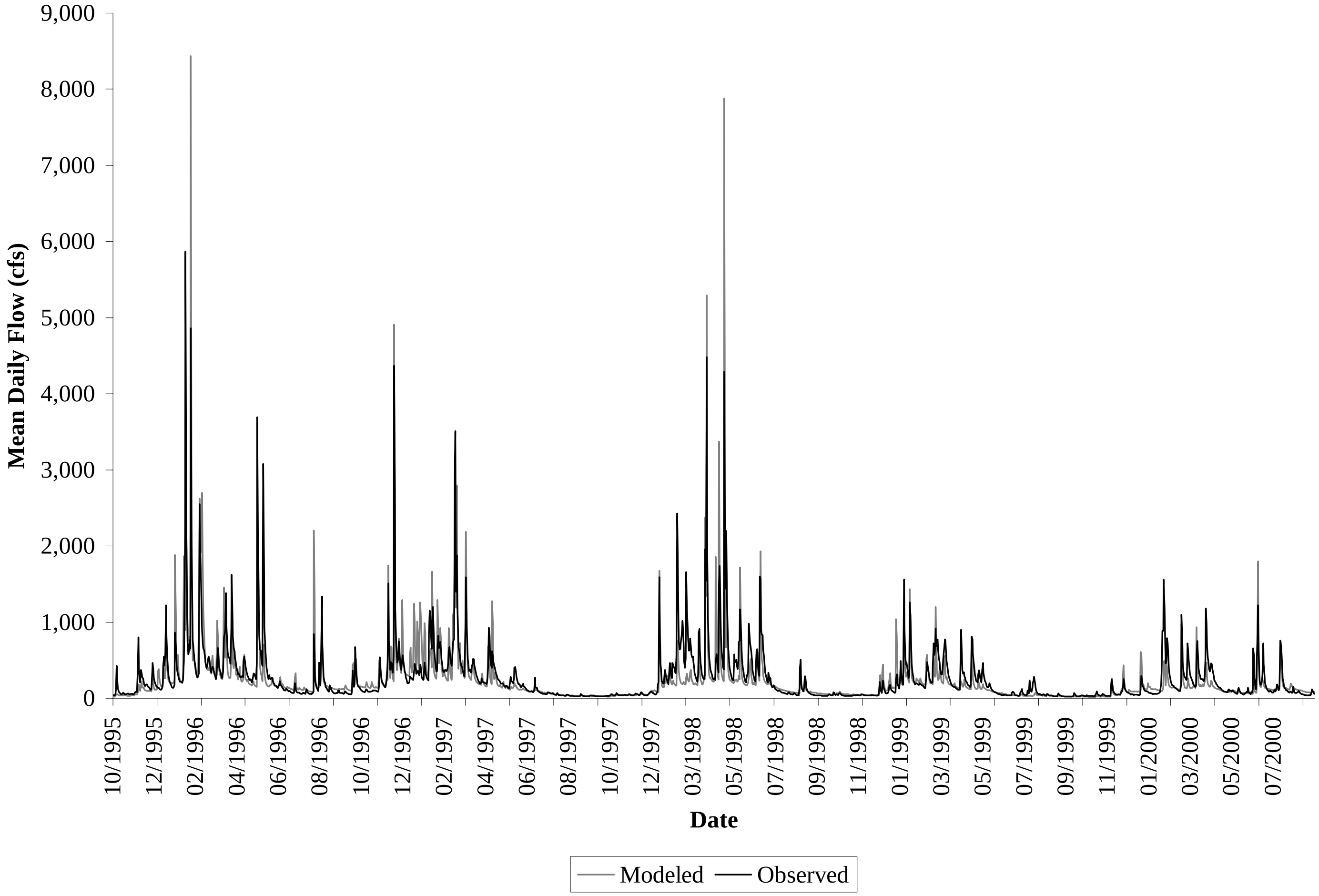

Figure 4.11 Hydrology calibration results for the Upper North Fork Holston River at subwatershed 6 (10/01/1995 through 9/30/2000).

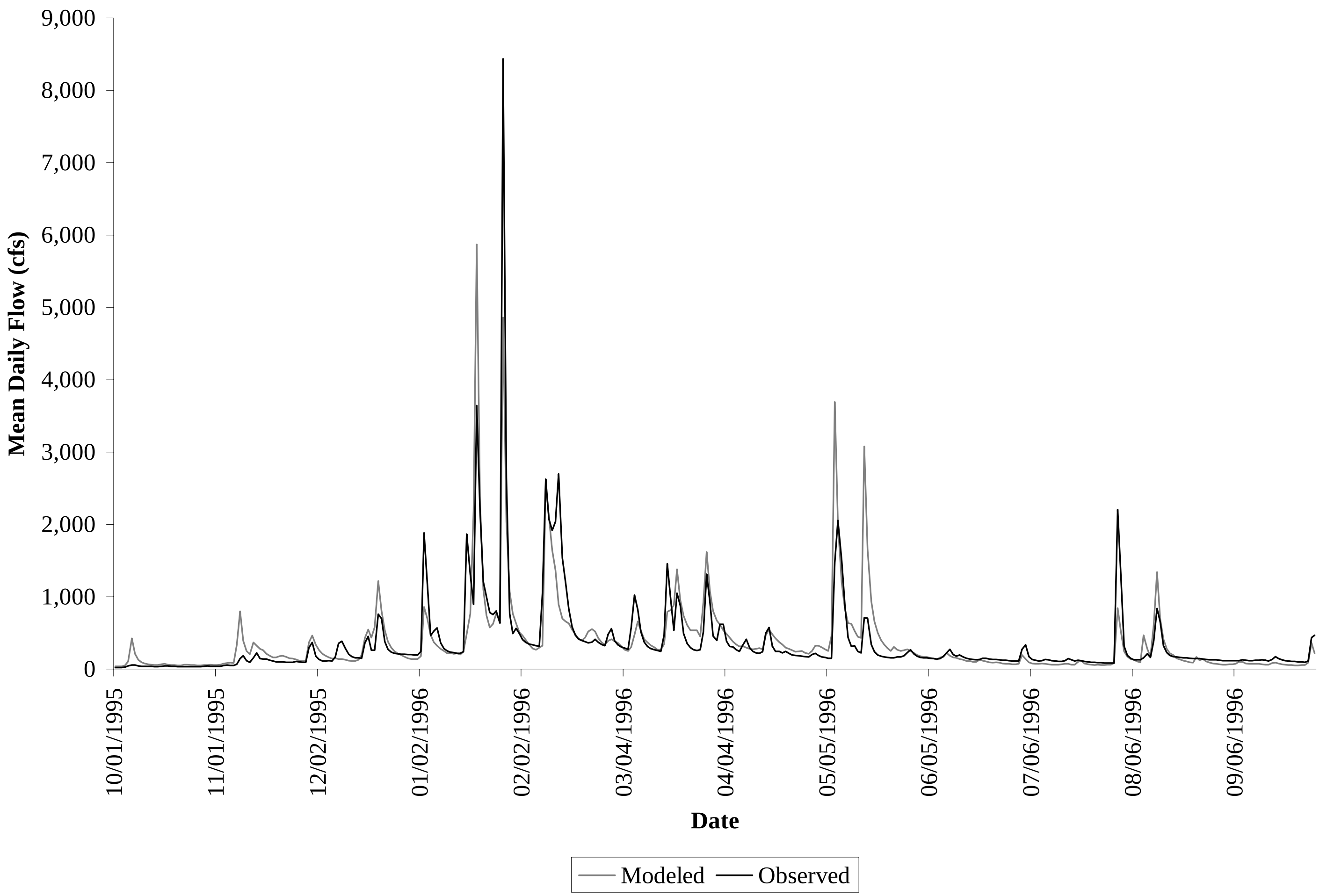

Figure 4.12 Hydrology calibration results for one year for the Upper North Fork Holston River at subwatershed 6 (10/01/1995 through 9/30/1996).

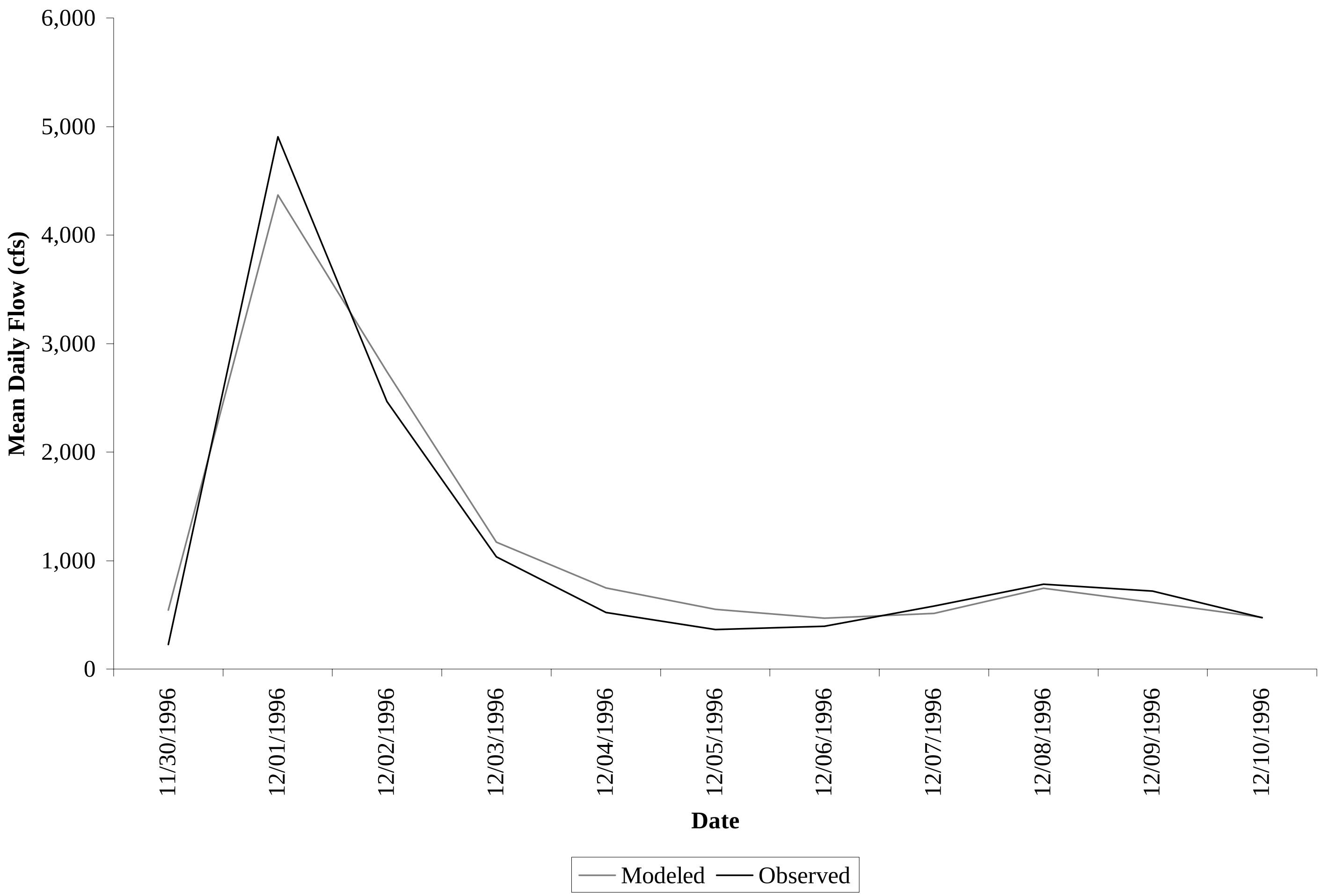

Figure 4.13 Hydrology calibration results for a single storm for the Upper North Fork Holston River at subwatershed 6 (11/30/1996 through 12/10/1996).

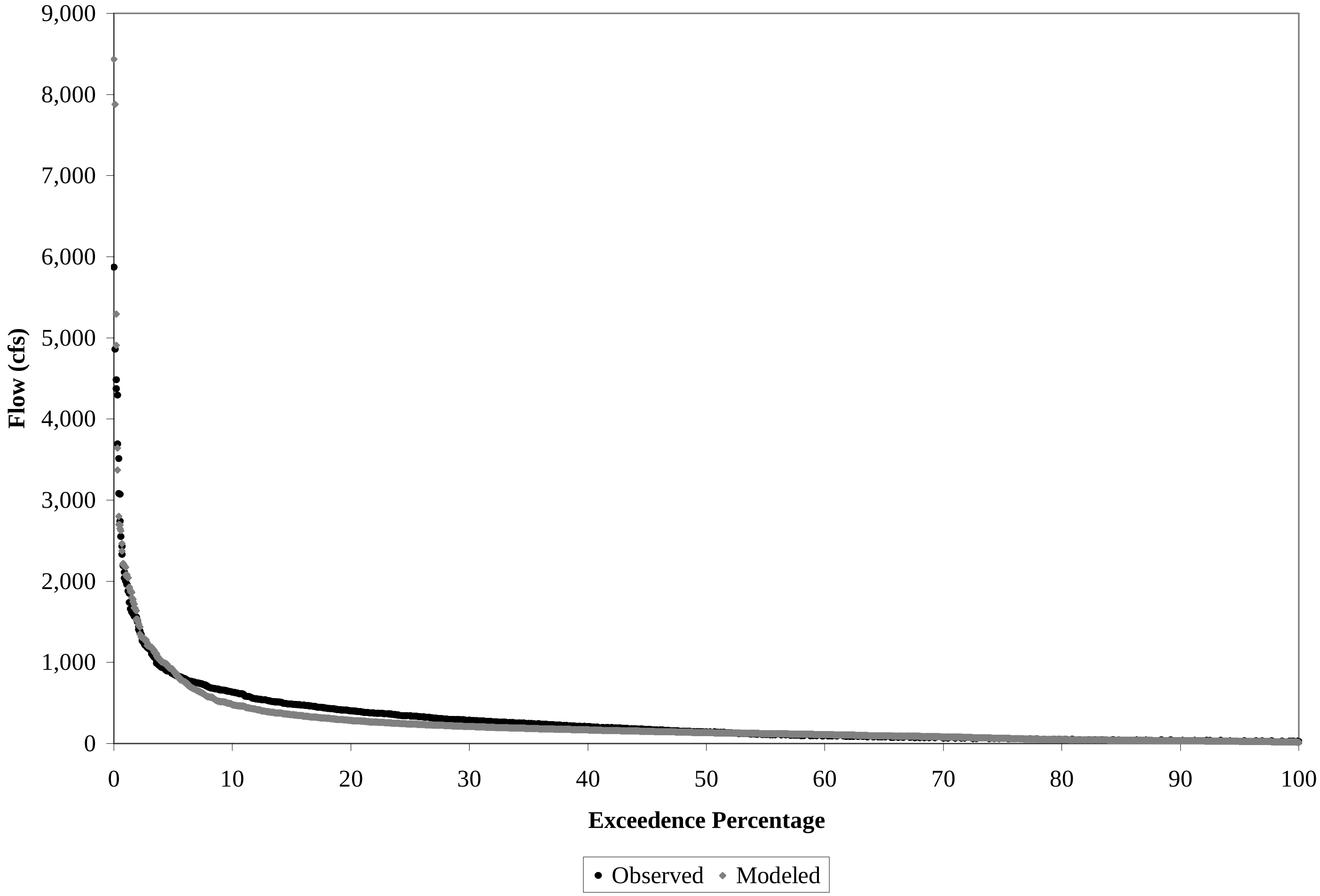

Figure 4.14 Upper North Fork Holston River flow duration at subwatershed 6 (10/01/1995 through 9/30/2000).

The hydrologic model was verified using stream flow data from 10/1/1991 to 9/30/1995. The resulting statistics are shown in Table 4.11. The percent error is within acceptable ranges for model validation. The hydrology validation results are shown in Figures 4.15 to 4.18.

Table 4.11 Hydrology validation criteria and model performance for the Upper North Fork Holston River (subwatershed 6) for the period 10/01/1991 through 9/30/1995.

	Observed	Modeled	Error
Total In-stream Flow:	76.00	70.99	-6.59%
Upper 10% Flow Values:	34.27	35.69	4.15%
Lower 50% Flow Values:	8.78	9.31	6.00%
Winter Flow Volume	38.97	36.59	-6.12%
Spring Flow Volume	20.66	15.09	-26.97%
Summer Flow Volume	5.13	5.02	-2.24%
Fall Flow Volume	11.24	14.30	27.24%
Total Storm Volume	68.14	64.68	-5.09%
Winter Storm Volume	37.03	35.02	-5.41%
Spring Storm Volume	18.70	13.51	-27.74%
Summer Storm Volume	3.16	3.43	8.83%
Fall Storm Volume	9.26	12.71	37.14%

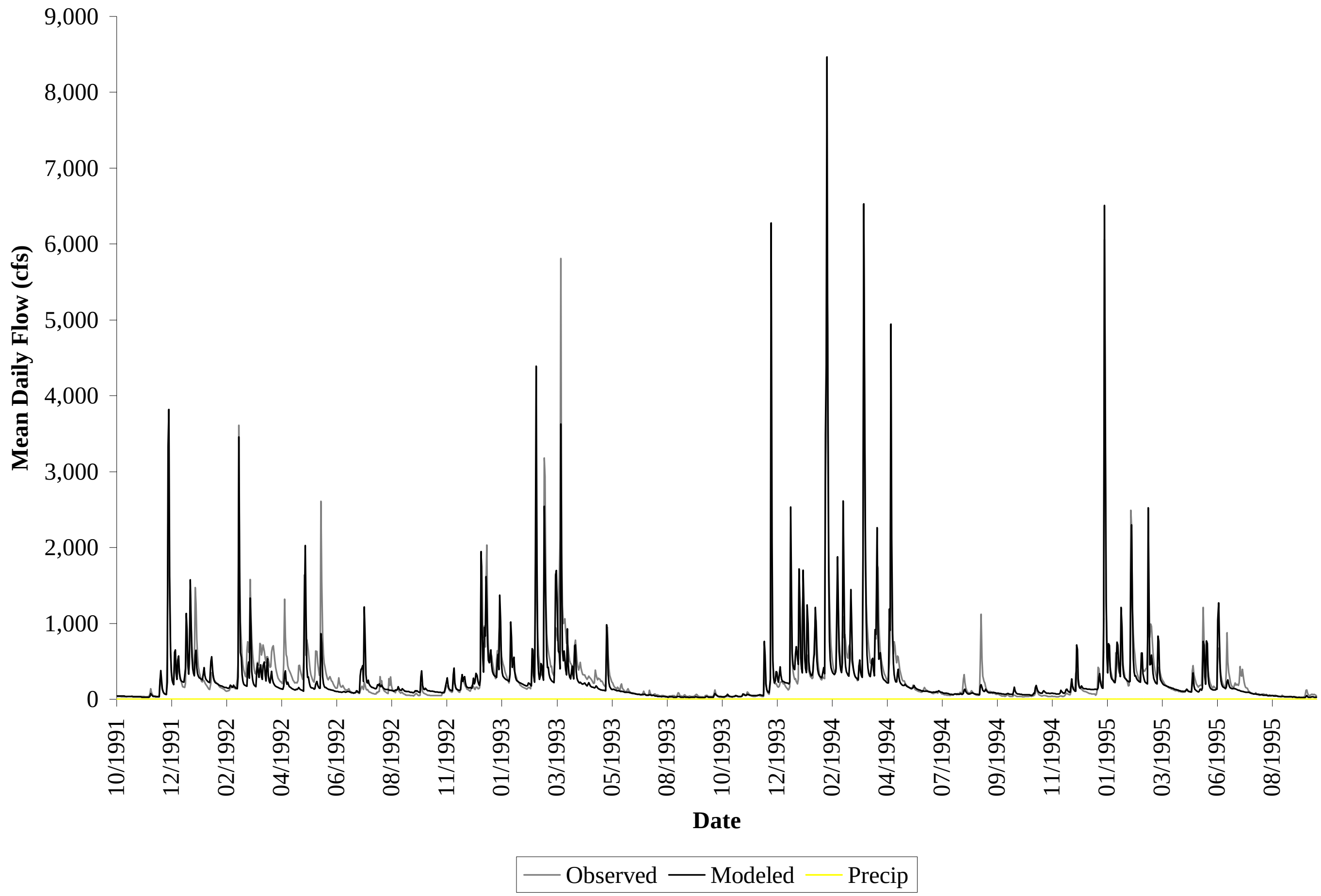

Figure 4.15 Hydrology validation results for the Upper North Fork Holston River at subwatershed 6 (10/01/1991 through 9/30/1995).

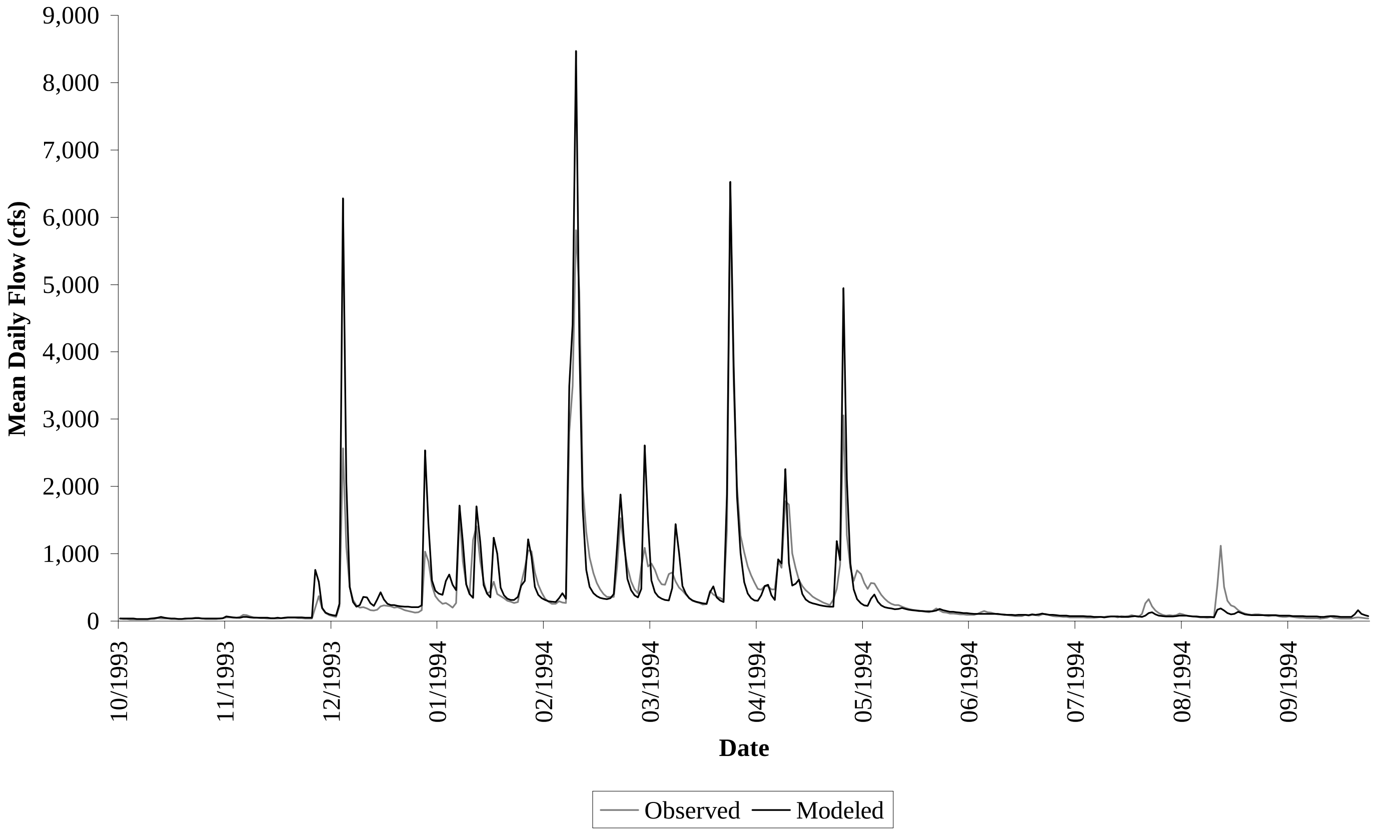

Figure 4.16 Hydrology validation results for one year for the Upper North Fork Holston River at subwatershed 6 (10/01/1993 through 9/30/1994).

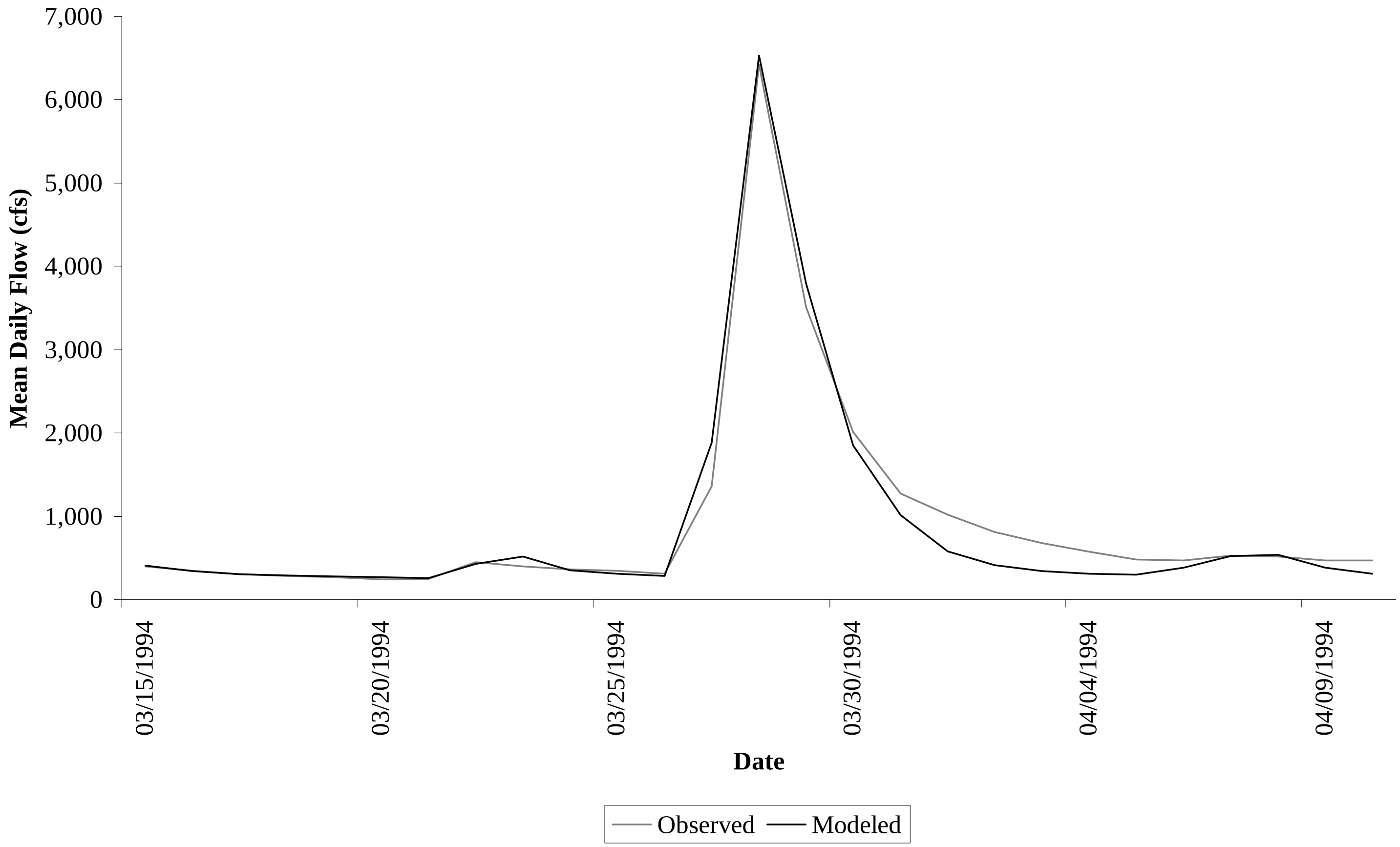

Figure 4.17 **Hydrology validation results for a single storm for the Upper North Fork Holston River at subwatershed 6 (3/15/1994 through 4/10/1994).**

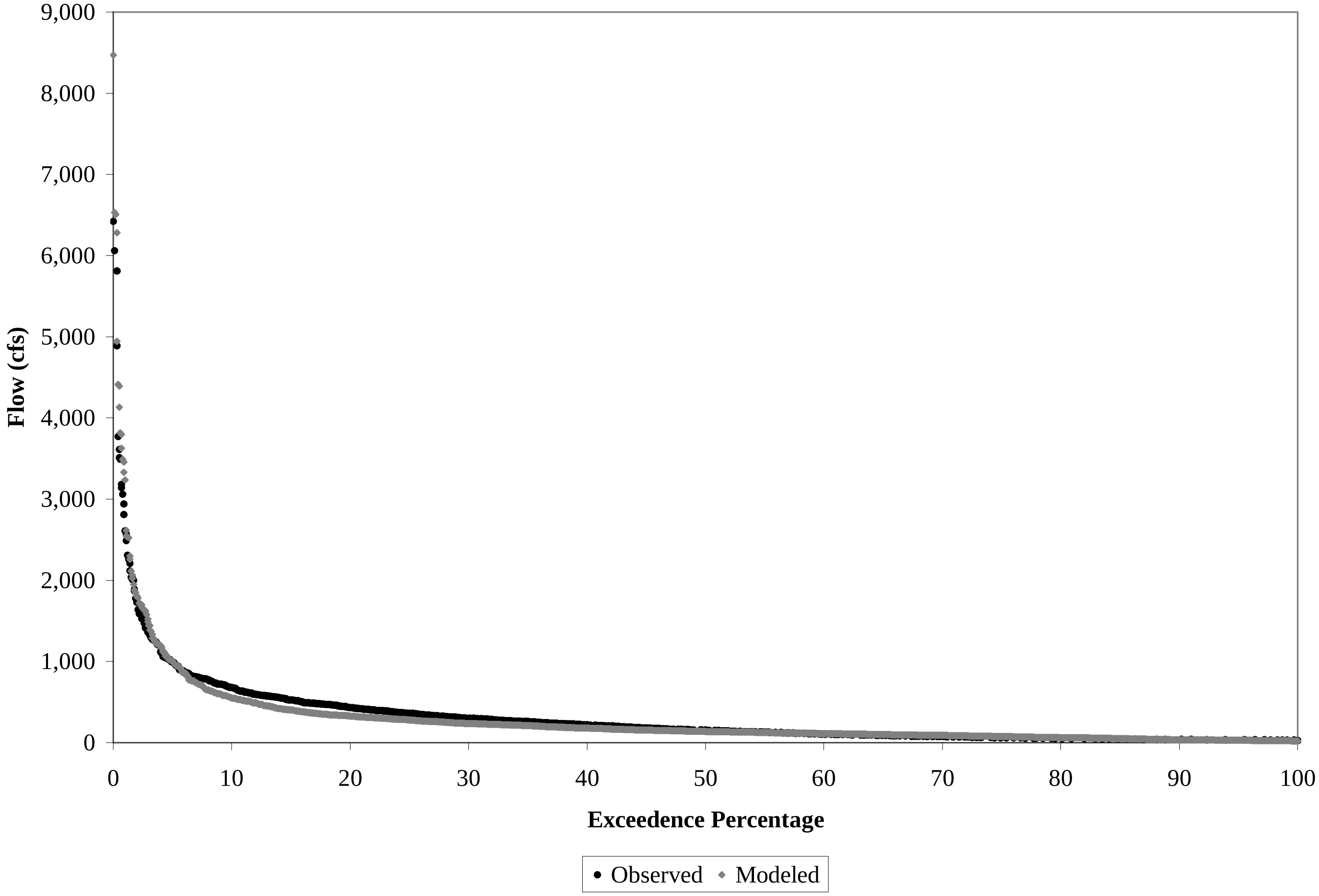

Figure 4.18 Upper North Fork Holston River flow duration at subwatershed 6 (10/01/1991 through 9/30/1995).

The hydrologic model was further verified using observed flow measurements at the stormwater culvert that drains the town of Saltville, Virginia. The outlet of subwatershed 20 represents this culvert. The data collected includes six measurements from 4/21/2005 to 5/20/2005. The results are shown in Figure 4.19. The town allowed ponds to fill during the week of May 14 for a fishing event for children, which lowered the flow leaving the town through the culvert.

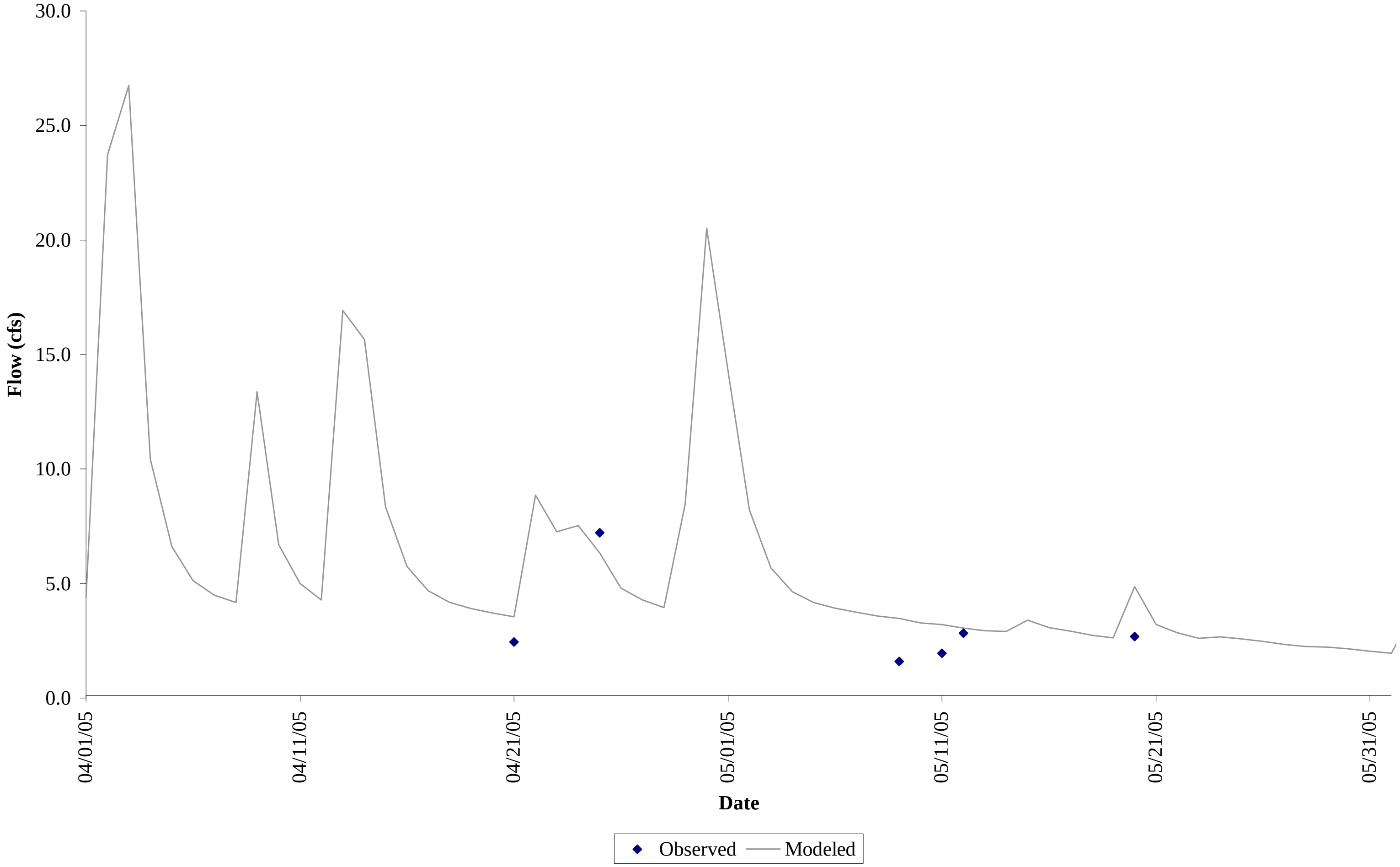

Figure 4.19 Hydrology validation results for Upper North Fork Holston River tributaries at the outlet of subwatershed 20 (4/1/2005 to 6/1/2005).

4.8.2 Water Quality Calibration and Validation

Water quality calibration is complicated by a number of factors, some of which are described here. Water quality concentrations (*e.g.*, chloride) are highly dependent on flow conditions. Observed data was available at the outlet of subwatersheds 3 and 5 and just downstream of the outlet of subwatersheds 6 and 7. This results in simulated and monitored data being compared at four locations throughout the watershed. Any variability associated with the modeling of stream flow compounds variability in modeling water quality parameters. Also, the concentration of pollutants can be highly variable; *e.g.*, chloride concentration spikes when salt is applied to roads. Grab samples are collected at a specific point in time and space, while the model predicts concentrations averaged over the entire stream reach and the duration of the time-step.

With a successful hydrology calibration, the water quality model was then calibrated. The water quality calibration was conducted using monitored data from 10/1/1990 through 9/30/1995. The process involved directly comparing modeled in-stream concentrations to observed data and adjusting appropriate model parameters within reasonable ranges. Observed data were obtained from various sources as described in previous sections. As with the hydrologic calibration, the objective of the water quality calibration was to minimize the difference between observed and modeled concentrations. Three parameters were utilized for model adjustment: concentration in interflow (MON-IFLW-CONC), concentration in groundwater (MON-GRND-CONC), and rate of surface runoff of concentration from land surfaces (WSQOP). All of these parameters were initially set at expected levels for the watershed conditions and adjusted within reasonable limits until an acceptable match between measured and modeled chloride concentrations was established (Table 4.12). Careful visual inspection of graphical comparisons between continuous simulation results and limited observed points was the primary tool used to guide the calibration process. Results of the calibration are presented in Figures 4.20 - 4.23. Table 4.13 shows the comparison statistics between simulated and monitored data at the four stations. It should be noted that for two of the four stations, chloride concentration was monitored for only a part of the five years of comparison. Therefore, statistics in Table 4.13 were calculated using only the common period between simulated and monitored data and not necessarily for the entire five years. The information in Table 4.13 and Figures in 4.20 - 4.23 indicates a good agreement between simulated and observed chloride concentrations.

Table 4.12 Model parameters utilized for water quality calibration.

Parameter	Units	Initial Parameter Estimate	Calibrated Parameter Value
MON-IFLW-CONC	mg/ft^3	100	144 – 2.16E+06
MON-GRND-CONC	mg/ft^3	100	36 – 5.41E+05
WSQOP	in/hr	0.10	0 – 14.28

Table 4.13 Statistics for chloride calibration model for Upper North Fork Holston River (10/1/1990 through 9/30/1995).

Subwatershed	Station	Average Simulated Value (mg/L)*	Average Monitored Value (mg/L)*	Maximum Simulated Value (mg/L)*	Maximum Monitored Value (mg/L)*	Minimum Simulated Value (mg/L)*	Minimum Monitored Value (mg/L)*	% Violation in Simulated*	% Violation in Monitored*
3	6CNFH097.67	3.24	2.20	31.81	2.7	1.16	1.80	0.00	0.00
5	6CNFH089.25	3.18	3.08	23.43	8.80	1.10	1.30	0.00	0.00
Just downstream of 6	6CNFH085.20	3.22	2.70	28.23	4.04	1.10	1.70	0.00	0.00
Just downstream of 7	6CNFH080.43	199.51	195.71	2047.39	951.00	20.75	7.80	27.48	28.00

Statistics were obtained over the common period between simulated and monitored data and not necessarily over the entire simulation period.

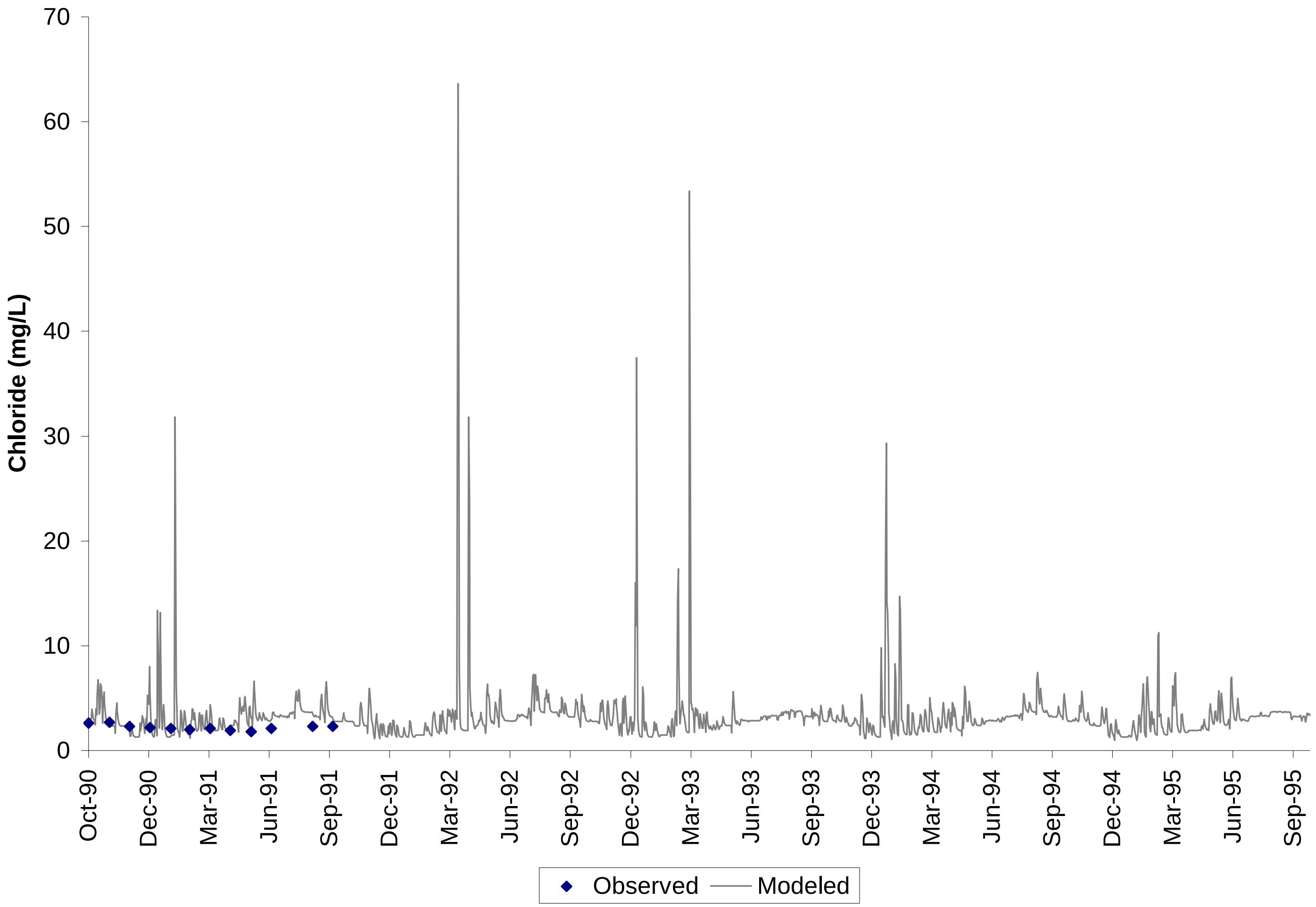

Figure 4.20 The modeled mean daily chloride concentrations compared to instantaneous observed chloride concentrations at station 6CNFH097.67 on Upper North Fork Holston River, during the calibration period (10/1/1990 – 9/30/1995).

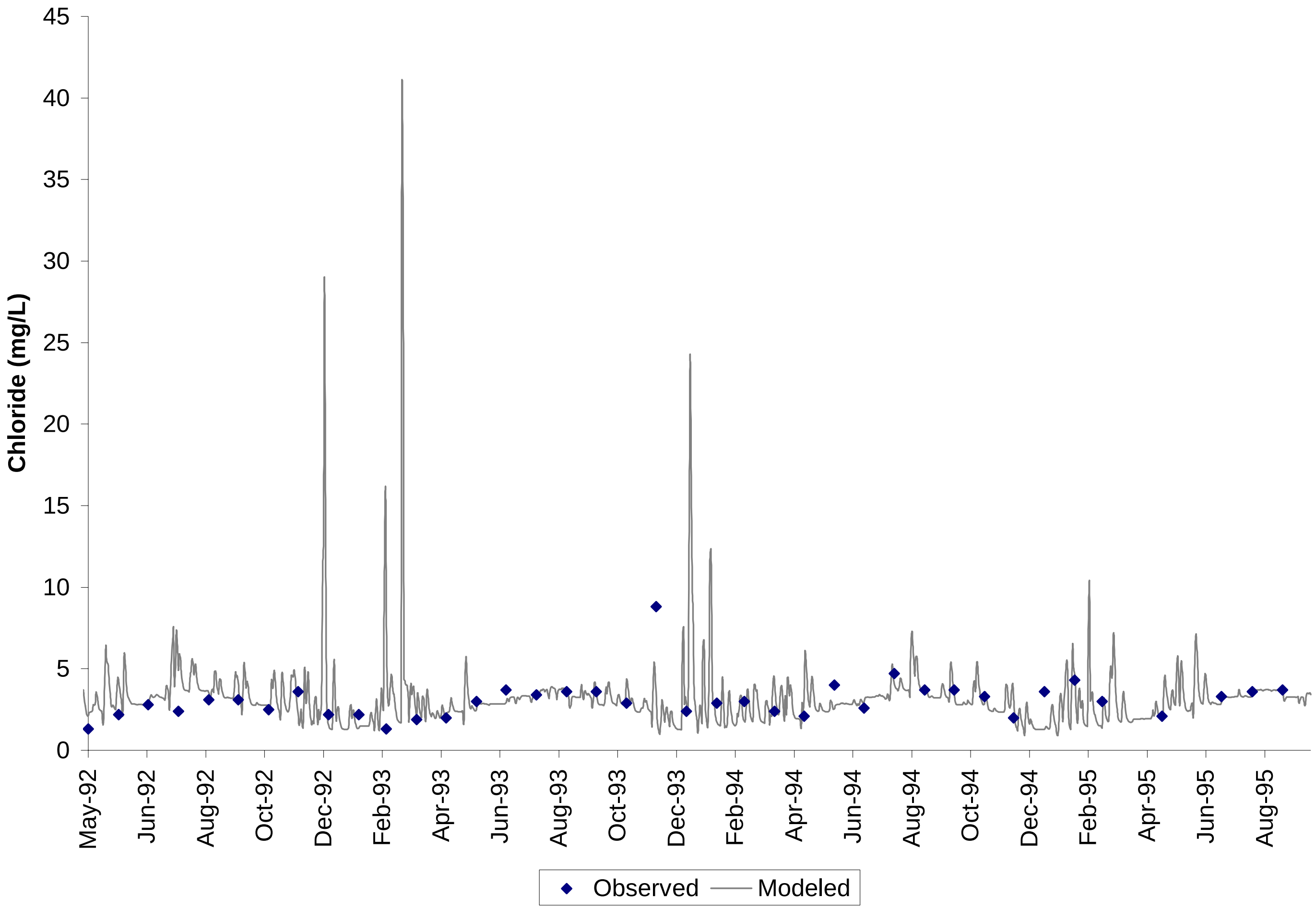

Figure 4.21 The modeled mean daily chloride concentrations compared to instantaneous observed chloride concentrations at station 6CNFH089.25 on Upper North Fork Holston River, during the calibration period (10/1/1990 – 9/30/1995).

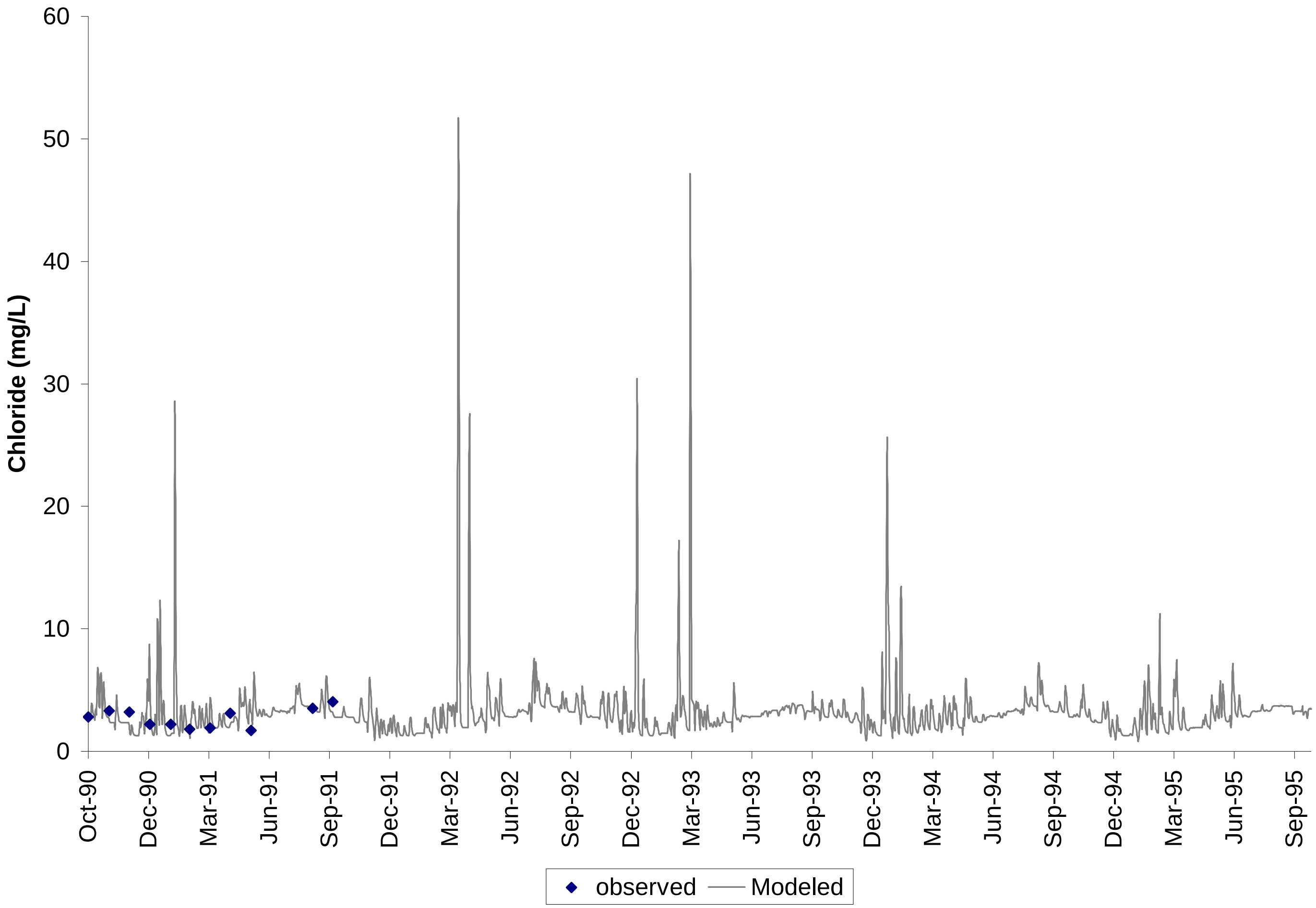

Figure 4.22 The modeled mean daily chloride concentrations compared to instantaneous observed chloride concentrations at station 6CNFH085.20 on Upper North Fork Holston River, during the calibration period (10/1/1990 – 9/30/1995).

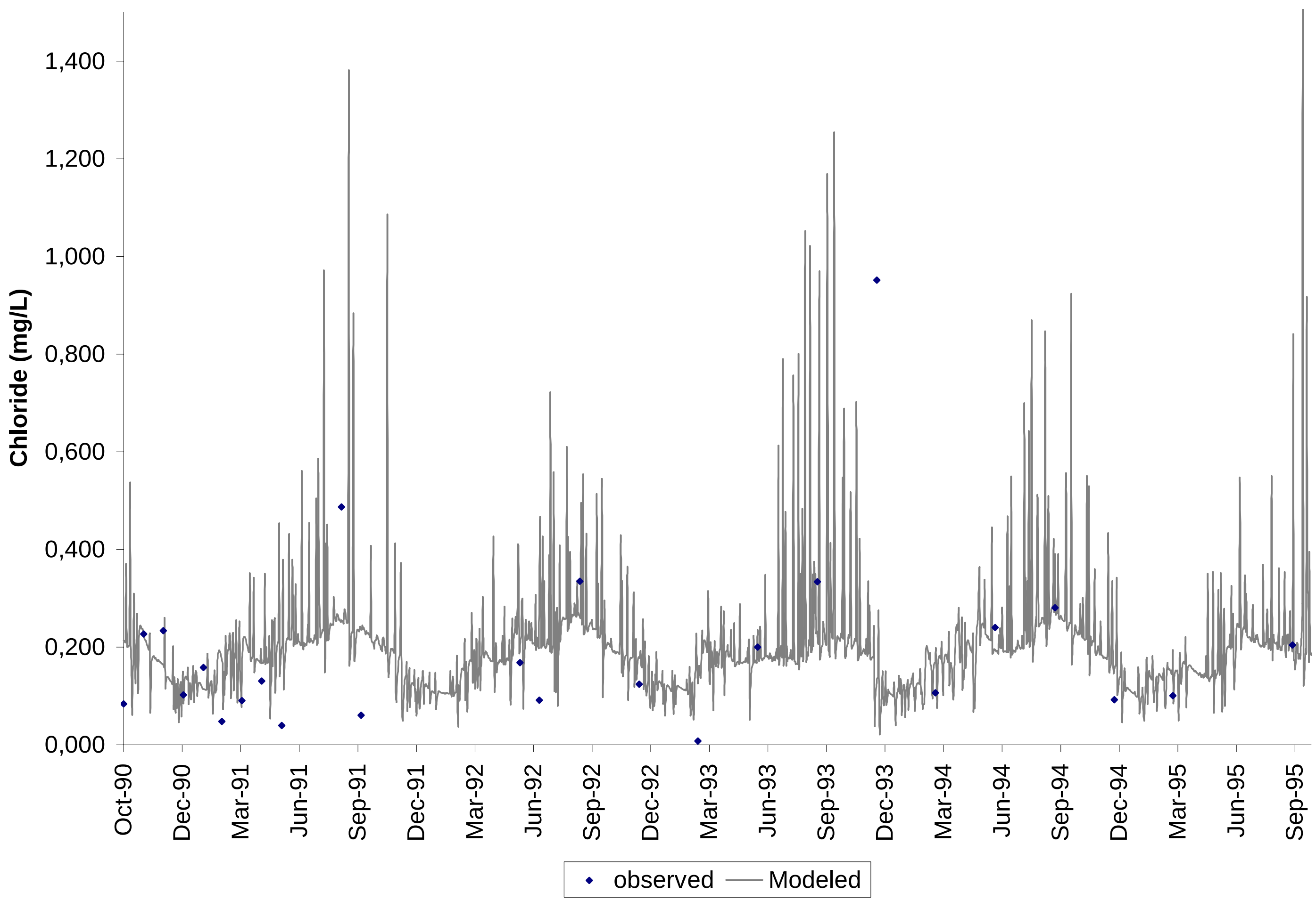

Figure 4.23 The modeled mean daily chloride concentrations compared to instantaneous observed chloride concentrations at station 6CNFH080.43 on Upper North Fork Holston River, during the calibration period (10/1/1990 – 9/30/1995).

Chloride water quality model validation was performed on data from 10/1/1995 to 9/30/2000. Observed data was available at the outlet of subwatershed 5 and just downstream of the outlet of subwatershed 7. The results shown in Table 4.14 and Figures 4.24 and 4.25 indicate a good agreement between simulated and monitored chloride concentrations for the validation period. The comparison in Table 4.15 between simulated and monitored chloride concentration at the four stations indicates that simulated concentrations contain the range of monitored data. Moreover, the simulated percent exceedance of the chloride standard closely resembles the monitored percent exceedance of standard.

Table 4.14 Statistics for the chloride validation model for Upper North Fork Holston River (10/1/1995 through 9/30/2000).

Subwatershed	Station	Average Simulated Value (mg/L)*	Average Monitored Value (mg/L)*	Maximum Simulated Value (mg/L)*	Maximum Monitored Value (mg/L)*	Minimum Simulated Value (mg/L)*	Minimum Monitored Value (mg/L)*	% Violation in Simulated*	% Violation in Monitored*
5	6CNFH089.25	3.67	5.32	57.34	9.60	1.16	2.70	0.00	0.00
Just downstream of 7	6CNFH080.43	199.52	161.55	1266.83	410.00	28.69	14.30	31.21	24.32

*Statistics were obtained over the common period between simulated and monitored data and not necessarily over the entire simulation period.

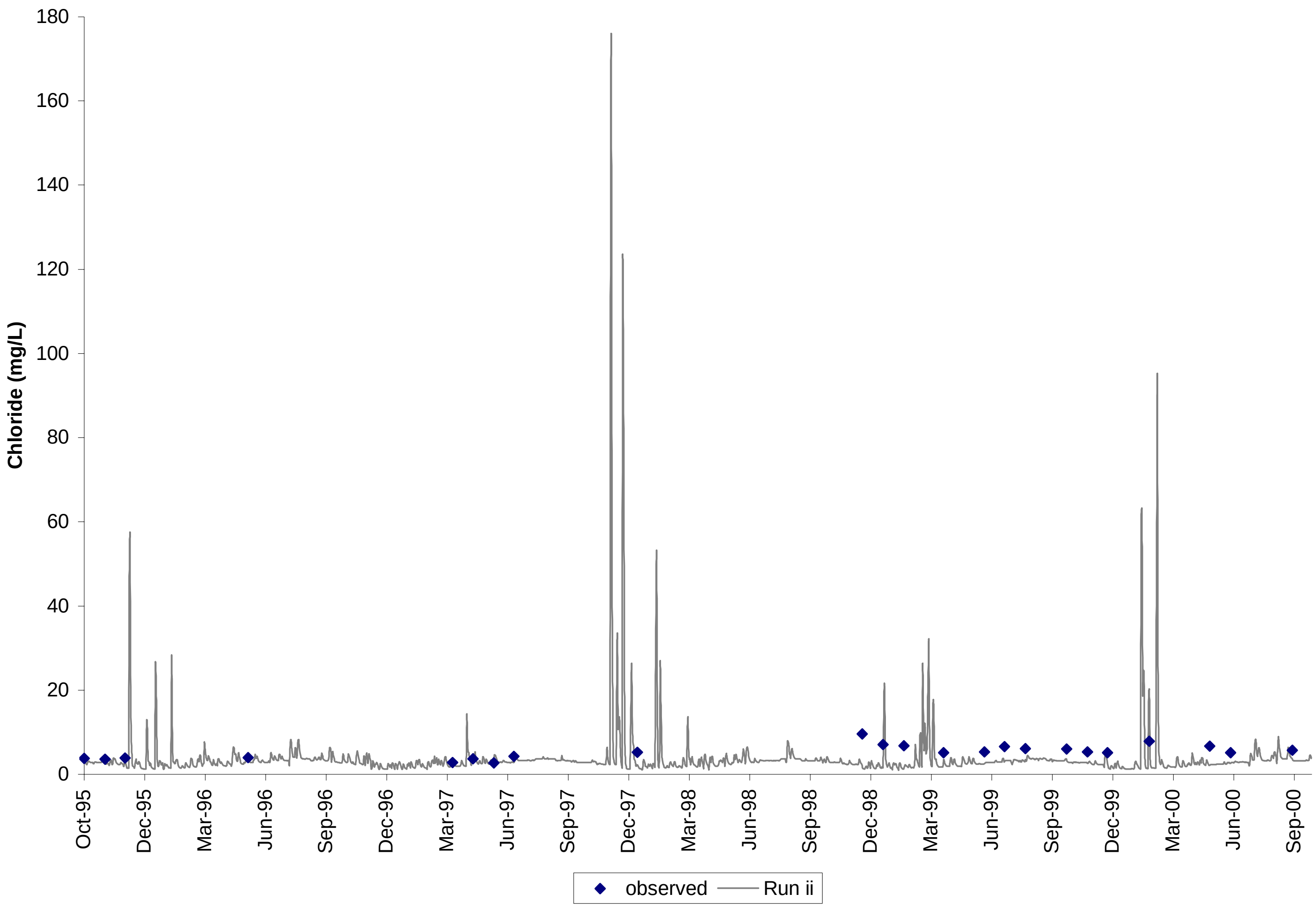

Figure 4.24 Mean daily modeled chloride concentrations compared to instantaneous observed chloride concentrations in Upper North Fork Holston River at the outlet of subwatershed 5 (10/1/1995 through 9/30/2000).

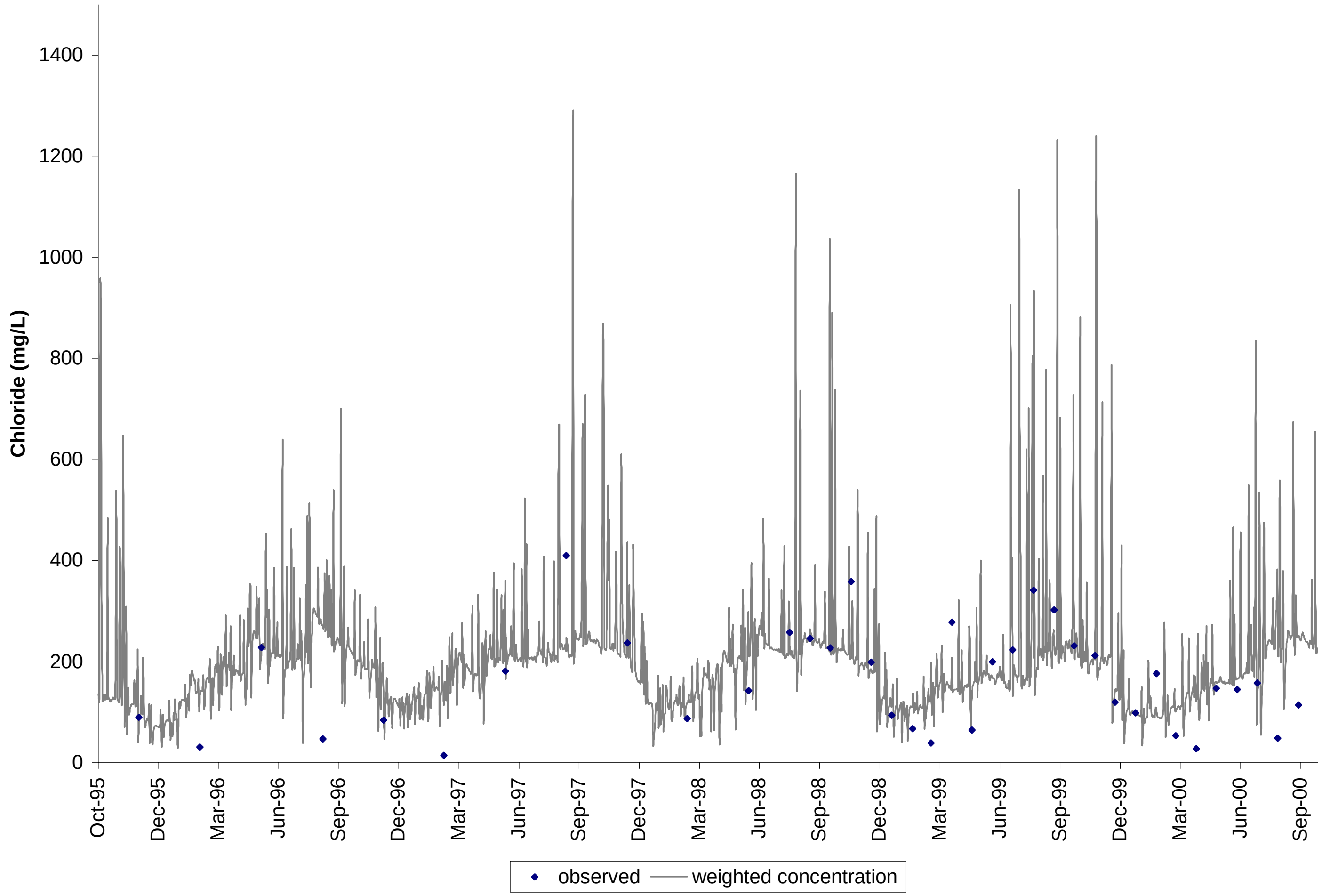

Figure 4.25 Mean daily modeled chloride concentrations compared to instantaneous observed chloride concentrations in Upper North Fork Holston River just below the outlet of subwatershed 7 (10/1/1995 through 9/30/2000).

5. ALLOCATION

Total Maximum Daily Loads consist of waste load allocations (WLAs, point sources) and load allocations (LAs, nonpoint sources), including natural background levels. Additionally, the TMDL must include a margin of safety (MOS) that either implicitly or explicitly accounts for uncertainties in the process. The definition is typically denoted by the expression:

$$\text{TMDL} = \text{WLAs} + \text{LAs} + \text{MOS}$$

The TMDL becomes the amount of a pollutant that can be assimilated by the receiving waterbody and still achieve water quality standards. For chloride, the TMDL is expressed in terms of loads (*e.g.*, kg/yr) or resulting concentration (*e.g.*, mg/L). This section describes the development of a TMDL for chloride for the Upper North Fork Holston River. The model was run for existing conditions over the period of October 1995 to September 2000.

5.1 Incorporation of a Margin of Safety

In order to account for uncertainty in modeled output, an MOS was incorporated into the TMDL development process. Individual errors in model inputs, such as data used for developing model parameters or data used for calibration, may affect the load allocations in a positive or a negative way. An MOS can be incorporated implicitly in the model through the use of conservative estimates of model parameters, or explicitly as an additional load reduction requirement. By adopting an implicit MOS in estimating the loads in the watershed, it is ensured that the recommended reductions will, in fact, succeed in meeting the water quality standard. Examples of implicit MOS used in the development of this TMDL are:

- Allocating permitted point sources at the maximum allowable fecal coliform concentration
- The selection of a modeling period that represented the critical hydrologic conditions in the watershed.

5.2 Scenario Development

The allocation scenario was modeled using HSPF. Existing conditions were adjusted until the TMDL endpoint was attained. The TMDL developed for the Upper North Fork Holston River was based on the VADEQ's chronic water quality standard, the four-day average chloride concentration of 230 mg/L. This average concentration was not to be violated more than once every three years, on average. Since the modeling period was five years, only one violation was allowed.

Pollutant concentrations were modeled over the entire duration of a representative modeling period, and pollutant loads were adjusted until the endpoint was met. The development of the allocation scenario was an iterative process that required numerous runs with each followed by an assessment of source reduction against the water quality target.

5.2.1 Wasteload Allocations

Six VPDES permitted point sources are currently permitted to discharge into the Upper North Fork Holston River but only four can be expected to discharge chlorides. Those four sources were modeled as point sources since no runoff event is required to deliver pollutants to the stream from these sources. The permit details in terms of outflow volume and chloride concentration are given in Chapter 4. The four point sources were allocated the maximum concentration for the period of simulation.

5.2.2 Load Allocations

Load allocations to nonpoint sources are divided into land-based loadings from land uses and directly applied loads in the stream (*e.g.*, uncontrolled residential discharges). Source reductions include those that are affected by both high and low flow conditions. In-stream chloride concentrations are highest during low flow conditions, but chloride concentrations spike during and after snowstorms due to application of salt to roads. Since the impairment continued from the outlet of subwatershed 8 through subwatershed 7, load allocation was performed for the outlet of both subwatersheds (Table 5.1).

Initially, uncontrolled residential discharges (*i.e.*, straight pipes) and overflows were reduced 100%. Also, contributions from two point sources that were no longer operating

(VA0070840 and VA0000876) were eliminated. This failed to reduce TDS to the target concentration. Additionally, contributions from failing septic systems were eliminated but, due to the small chloride contribution, this did not result in any noticeable reduction in concentration of chloride at the watershed outlet (subwatershed 8) and the outlet of subwatershed 7.

Additional scenarios that achieved considerable reductions in chloride concentration are shown in Table 5.1 along with the existing conditions scenario. In those scenarios, chloride load in interflow (IOQC), and groundwater (AOQC) were reduced until the modeled chloride concentration for the modeling period met the chloride concentration standard. Those reductions were made locally to subwatershed 20 that included the outflow from the salt spring. No reductions in IOQC and AOQC were made to the rest of the watershed since reductions made to subwatershed 20 achieved the allocation goal of meeting the chloride standard. Allocation scenarios for chloride in the Upper North Fork Holston River are given in Table 5.1. The final TMDL loads for chloride in the Upper North Fork Holston are represented in Table 5.2. Figure 5.1 shows the existing and allocated conditions at the outlet of subwatershed 7 and Figure 5.2 shows the existing and allocated conditions at the outlet of the whole watershed.

Table 5.1 Allocation scenarios for chloride concentration with current loading estimates in the Upper North Fork Holston River impairment.

Scenario Number	At Outlet of Sub-watershed	Percent Reduction in Loading from Existing Condition						No. of Violations	Percent Violations
		Straight Pipes	Septic Systems	Sewer Overflows	Non-active Point Sources	IOQC in sub-watershed 20	AOQC in sub-watershed 20	4-day Average > 230 mg/L	4-day Average > 230 mg/L
1 (existing)	7	0	0	0	0	0	0	800	43.88
	8	0	0	0	0	0	0	415	22.74
2	7	100	100	100	100	30.6	30.6	191	10.48
	8	100	100	100	100	30.6	30.6	96	5.26
3	7	100	100	100	100	73.3	73.3	1	0.05
	8	100	100	100	100	73.3	73.3	0	0.00

Table 5.2 Allocated chloride TMDL contributions from land based (LA) and point sources (WLA) in the Upper North Fork Holston River.

Impairment	WLA (kg/year)	LA (kg/year)	MOS	TMDL (kg/year)
Upper North Fork Holston River	380,738	10,629,462	*Implicit*	11,010,200
VAG400080	*35*			
VA0026808	*44,679*			
VAG400145	*35*			
VA0090115	*335,989*			

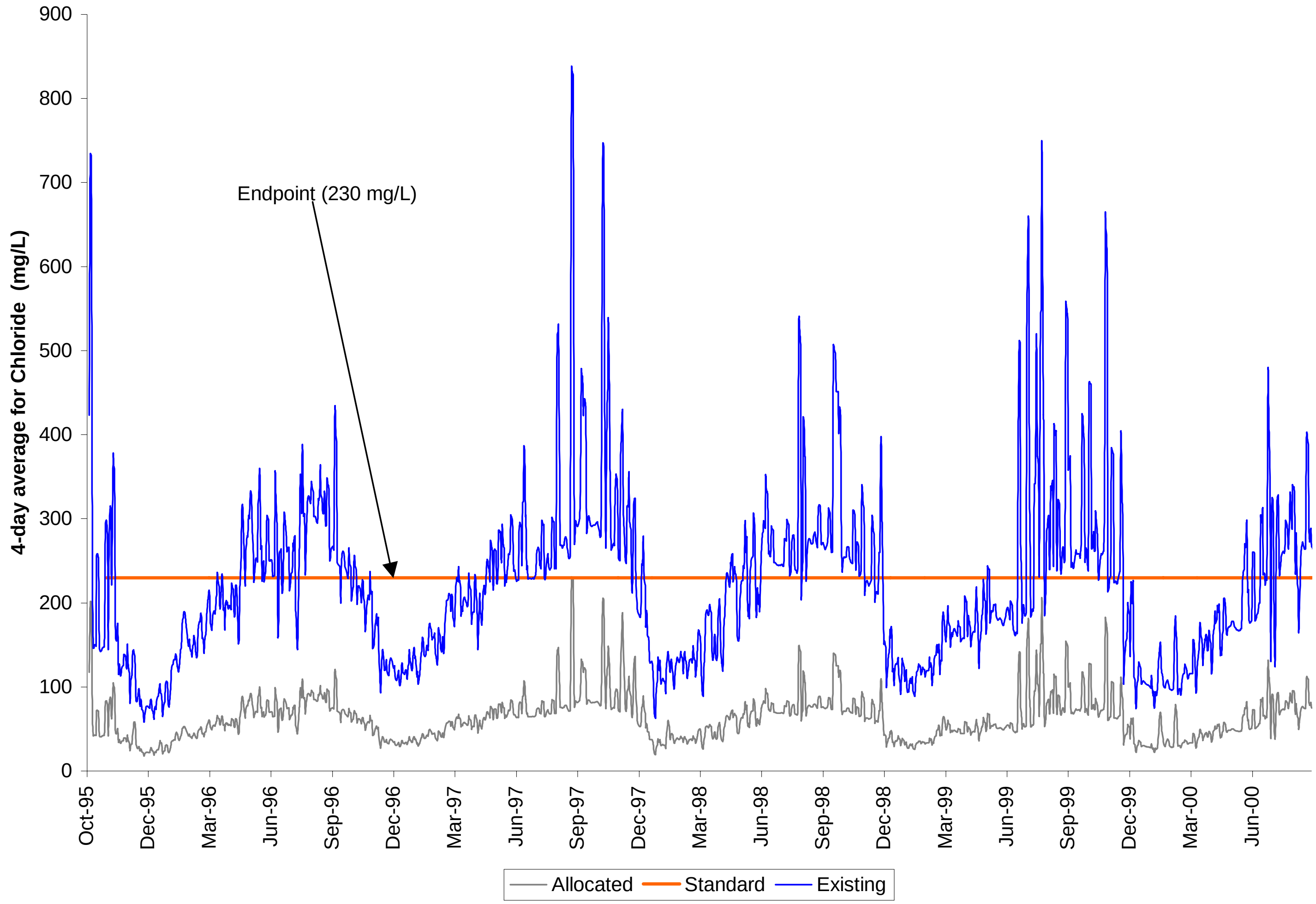

Figure 5.1 Four-day chloride concentrations for the Upper North Fork Holston impairment at outlet of subwatershed 7 under existing and allocated conditions.

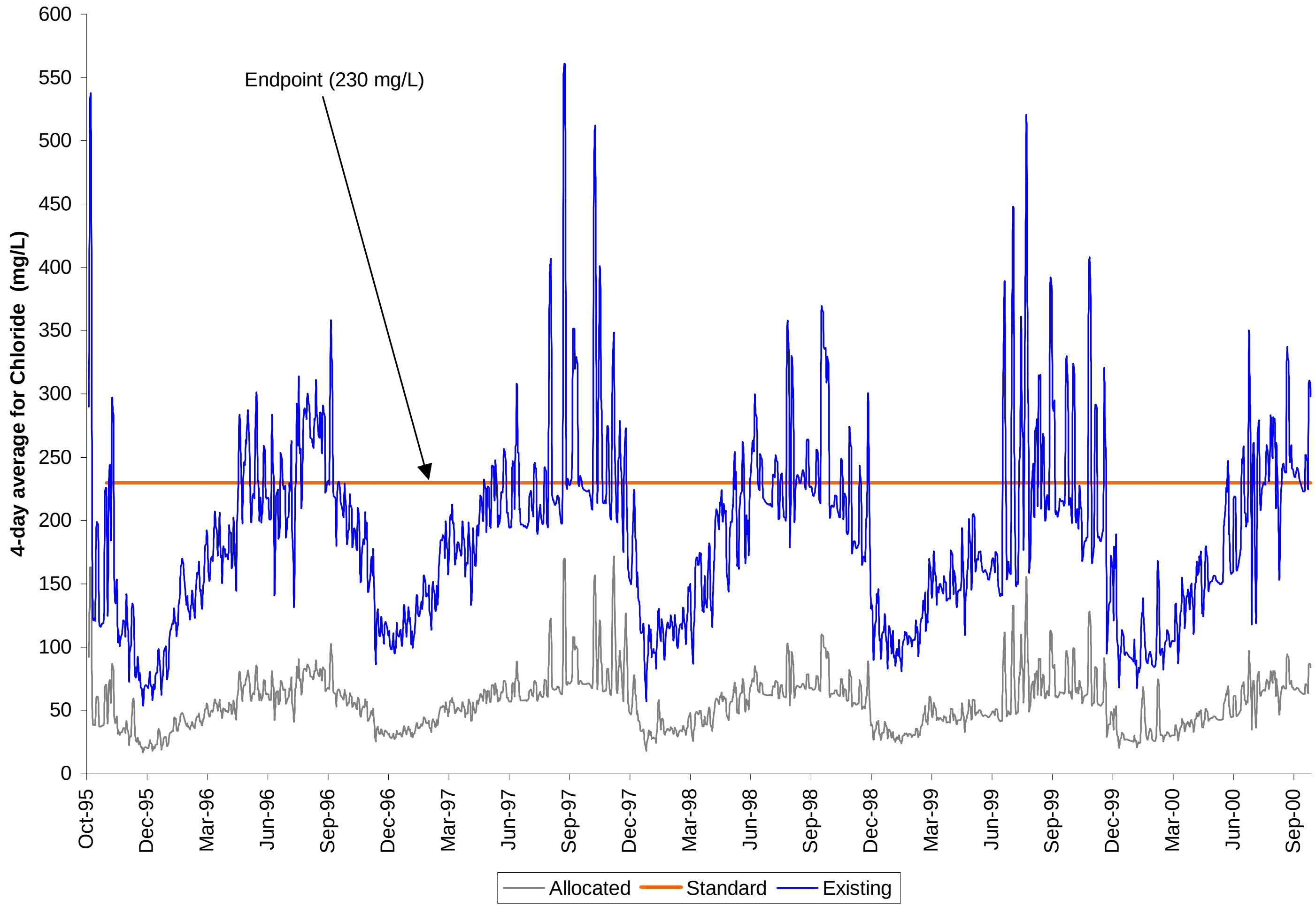

Figure 5.2 **Four-day chloride concentrations for the Upper North Fork Holston impairment at main watershed outlet under existing and allocated conditions**

6. IMPLEMENTATION

Once a TMDL has been approved by the EPA, measures must be taken to reduce pollution levels from both point and nonpoint sources in the stream (see section 6.4.2). For point sources, all new or revised VPDES/NPDES permits must be consistent with the TMDL WLA pursuant to 40 CFR '122.44 (d)(1)(vii)(B) and must be submitted to the EPA for approval. The measures for nonpoint source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan (IP). The process for developing an implementation plan has been described in the *TMDL Implementation Plan Guidance Manual*, published in July 2003 and available upon request from the VADEQ and VADCR TMDL project staff or at http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf. With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

6.1 Staged Implementation

In general, Virginia intends for the required BMPs to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;
2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;
3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;
4. It helps ensure that the most cost effective practices are implemented first; and
5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL IP. Specific goals for BMP implementation will be established as part of the IP development.

6.2 Stage 1 Scenarios

Implementation of BMPs in the watershed will occur in stages. The benefit of staged implementation is that it provides a mechanism for developing public support and for evaluating the efficacy of the TMDL in achieving the water quality standard.

It is anticipated that management of the salt ponds by the Town of Saltville will be the initial target of implementation. The source of the majority of the chlorides in the Saltville area is natural due to geologic deposition of salt deposits. The primary source of the chlorides entering the Upper North Fork Holston River is from a culvert that drains the Town. A large pond that receives flow from a salt spring drains to this culvert. The Town of Saltville periodically adjusts the water level in the pond by reducing or increasing the overflow from the pond to the culvert. The Town should ensure that when it is necessary to lower the volume of the pond, the overflow should be carefully controlled. Water should be released at a very slow rate over a period of days especially during times of low flow in the Upper North Fork Holston River.

Table 6.1 illustrates the effect that the reductions have on the impaired segment of the North Fork Holston River. These scenario were selected because they were most likely to make a significant reduction in chloride concentrations.

Table 6.1 Stage 1 implementation scenario for the Upper North Fork Holston impairment.

At Outlet of Sub-watershed	Percent Reduction in Loading from Existing Condition						No. of Violations	Percent Violations
	Straight Pipes	Septic Systems	Sewer Overflows	Non-active Point Sources	IOQC in sub-watershed 20	AOQC in sub-watershed 20	4-day Average > 230 mg/L	4-day Average > 230 mg/L
7	100	100	100	100	30.6	30.6	191	10.48
8	100	100	100	100	30.6	30.6	96	5.26

6.3 Ongoing Restoration Efforts

Implementation of this TMDL will contribute to ongoing water quality improvement efforts aimed at restoring water quality in Virginia’s streams.

6.3.1 Follow-Up Monitoring

Following the development of the TMDL, the VADEQ will make every effort to continue to monitor the impaired stream in accordance with its ambient and biological monitoring programs. VADEQ's Ambient Watershed Monitoring Plan for conventional pollutants calls for watershed monitoring to take place on a rotating basis, bi-monthly for two consecutive years of a six-year cycle. In accordance with Guidance Memo No. 03-2004 (VADEQ, 2003), during periods of reduced resources monitoring can temporarily discontinue until the TMDL staff determines that implementation measures to address the source(s) of impairments are being installed. Monitoring can resume at the start of the following fiscal year, next scheduled monitoring station rotation, or where deemed necessary by the regional office or TMDL staff, as a new special study. Since there may be a lag time of one-to-several years before any improvement in the benthic community will be evident, follow-up biological monitoring may not have to occur in the fiscal year immediately following the implementation of control measures.

The purpose, location, parameters, frequency, and duration of the monitoring will be determined by the VADEQ staff, in cooperation with the VADCR staff, the Implementation Plan Steering Committee, and local stakeholders. Whenever possible, the location of the follow-up monitoring station(s) will be the same as the listing station. At a minimum, the monitoring station must be representative of the original impaired segment. The details of the follow-up monitoring will be outlined in the Annual Water Monitoring Plan prepared by each VADEQ Regional Office. Other agency personnel, watershed stakeholders, etc., may provide input on the Annual Water Monitoring Plan. These recommendations must be made to the VADEQ regional TMDL coordinator by September 30 of each year.

VADEQ staff, in cooperation with VADCR staff, the Implementation Plan Steering Committee and local stakeholders, will continue to use data from the ambient monitoring stations to evaluate reductions in pollutants ("water quality milestones" as established in the IP), the effectiveness of the TMDL in attaining and maintaining water quality standards, and the success of implementation efforts. Recommendations may then be made, when necessary, to target implementation efforts in specific areas and continue or discontinue monitoring at follow-up stations.

In some cases, watersheds will require monitoring above and beyond what is included in VADEQ's standard monitoring plan. Ancillary monitoring by citizens, watershed groups, local government, or universities is an option that may be used in such cases. An effort should be made to ensure that ancillary monitoring follows established QA/QC guidelines in order to maximize compatibility with VADEQ monitoring data. In instances where citizens' monitoring data is not available and additional monitoring is needed to assess the effectiveness of targeting efforts, TMDL staff may request that the monitoring managers in each regional office increase the number of stations or monitor existing stations at a higher frequency in the watershed. The additional monitoring beyond the original bimonthly single station monitoring will be contingent on staff resources and available laboratory budget. More information on citizen monitoring in Virginia and QA/QC guidelines is available at http://www.deq.virginia.gov/cmonitor/.

To demonstrate that water quality standards are being met in watersheds where corrective actions have taken place (whether or not a TMDL or IP has been completed), VADEQ must meet the minimum data requirements from the original listing station or a station representative of the originally listed segment. The minimum data requirement for conventional pollutants (bacteria, dissolved oxygen, etc.) is bimonthly monitoring for two consecutive years. For biological monitoring, the minimum requirement is two consecutive samples (one in the spring and one in the fall) in a one-year period.

VADEQ will monitor at biological monitoring station 6CNFH080.45 as implementation of corrective actions in the watershed occurs in order to assess the achievement of the Stage 1 implementation goals. Monitoring after corrective actions occur allows the most effective use of monitoring resources in the regional office. VADEQ will use data from this monitoring station to evaluate improvements in the benthic community and the effectiveness of TMDL implementation in attainment of the general water quality standard.

6.3.2 Regulatory Framework

While section 303(d) of the CWA and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented.

EPA also requires that all new or revised National Pollutant Discharge Elimination System (NPDES) permits must be consistent with the TMDL WLA pursuant to 40 CFR §122.44 (d)(1)(vii)(B). All such permits should be submitted to the EPA for review.

Additionally, Virginia's 1997 Water Quality Monitoring, Information and Restoration Act (WQMIRA) directs the State Water Control Board (SWCB) to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). WQMIRA also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary, and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 *Guidance for Water Quality-Based Decisions: The TMDL Process.* The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans and milestones for attaining water quality standards.

For the implementation of the WLA component of the TMDL, the Commonwealth intends to utilize the VPDES program, which typically includes consideration of the WQMIRA requirements during the permitting process. Requirements of the permit process should not be duplicated in the TMDL process and, with the exception of stormwater related permits, permitted sources are not usually addressed during the development of a TMDL implementation plan.

For the implementation of the TMDL's LA component, a TMDL implementation plan addressing the WQMIRA requirements, at a minimum, will be developed. An exception are the municipal separate storm sewer systems (MS4s) which are both covered by NPDES permits and expected to be included in TMDL implementation plans, as described in the stormwater permit section below.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the TMDL implementation plan. Regional and local offices of VADEQ, VADCR, and other cooperating agencies are technical resources to assist in this endeavor.

In response to a Memorandum of Understanding (MOU) between EPA and VADEQ, VADEQ submitted a draft Continuous Planning Process to EPA in which VADEQ commits to regularly updating the state's Water Quality Management Plans (WQMPs). The WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

VADEQ staff will present both EPA-approved TMDLs and TMDL implementation plans to the SWCB for inclusion in the appropriate Water Quality Management Plan (WQMP), in accordance with the CWA's Section 303(e) and Virginia's Public Participation Guidelines for Water Quality Management Planning.

VADEQ staff will also request that the SWCB adopt TMDL WLAs as part of the Water Quality Management Planning Regulation (9VAC 25-720), except in those cases when permit limitations are equivalent to numeric criteria contained in the Virginia Water Quality Standards, such as is the case for bacteria. This regulatory action is in accordance with §2.2-4006A.4.c and §2.2-4006B of the Code of Virginia. SWCB actions relating to water quality management planning are described in the public participation guidelines referenced above and can be found on VADEQ's web site under http://www.deq.state.va.us/tmdl/pdf/ppp.pdf

6.3.3 Stormwater Permits

VADEQ and VADCR coordinate separate State programs that regulate the management of pollutants carried by stormwater runoff. VADEQ regulates storm water discharges associated with "industrial activities", while VADCR regulates storm water discharges from construction sites, and from municipal separate storm sewer systems (MS4s).

EPA approved VADCR's VPDES stormwater program on December 30, 2004. VADCR's regulations became effective on January 29, 2005. VADEQ is no longer the regulatory agency responsible for administration and enforcement of the VPDES MS4 and construction stormwater permitting programs. More information is available on VADCR's web site through the following link: http://www.dcr.virginia.gov/sw/vsmp

It is the intention of the Commonwealth that the TMDL will be implemented using existing regulations and programs. One of these regulations is VADCR's Virginia Stormwater

Management Program (VSMP) Permit Regulation (4 VAC 50-60-10 et. seq). Section 4VAC 50-60-380 describes the requirements for stormwater discharges. Also, federal regulations state in 40 CFR §122.44(k) that NPDES permit conditions may consist of "Best management practices to control or abate the discharge of pollutants when: …(2) Numeric effluent limitations are infeasible…"

For MS4/VSMP general permits, the Commonwealth expects the permittee to specifically address the TMDL wasteload allocations for stormwater through the implementation of programmatic BMPs. BMP effectiveness would be determined through ambient in-stream monitoring. This is in accordance with recent EPA guidance (EPA Office of Water, 2002). If future monitoring indicates no improvement in stream water quality, the permit could require the MS4 to expand or better tailor its stormwater management program to achieve the TMDL wasteload allocation. However, only failing to implement the programmatic BMPs identified in the modified stormwater management program would be considered a violation of the permit. Any changes to the TMDL resulting from water quality standards changes on Upper North Fork Holston River would be reflected in the permit.

Wasteload allocations for stormwater discharges from storm sewer systems covered by a MS4 permit will be addressed in TMDL implementation plans. An implementation plan will identify types of corrective actions and strategies to obtain the wasteload allocation for the pollutant causing the water quality impairment. Permittees need to participate in the development of TMDL implementation plans since recommendations from the process may result in modifications to the stormwater management plan in order to meet the TMDL.

Additional information on Virginia's Stormwater Phase 2 program and a downloadable menu of Best Management Practices and Measurable Goals Guidance can be found at http://www.dcr.virginia.gov/sw/vsmp.htm.

6.3.4 Implementation Funding Sources

Cooperating agencies, organizations and stakeholders must identify potential funding sources available for implementation during the development of the implementation plan in accordance with the "Virginia Guidance Manual for Total Maximum Daily Load Implementation Plans". Potential sources for implementation may include the U.S.

Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, EPA Section 319 funds, the Virginia State Revolving Loan Program, Virginia Agricultural Best Management Practices Cost-Share Programs, the Virginia Water Quality Improvement Fund, tax credits, and landowner contributions. The *Guidance Manual for Total Maximum Daily Load Implementation Plans* contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

6.3.5 Attainability of Designated Uses

In some streams for which TMDLs have been developed, factors may prevent the stream from attaining its designated use.

In order for a stream to be assigned a new designated use, the current designated use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of the contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable BMPs for nonpoint source control (9 VAC 25-260-10). This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process. Additional information can be obtained at http://www.deq.virginia.gov/wqs/WQS03AUG.pdf

The process to address potentially unattainable reductions based on the above is as follows: First is the development of a Stage 1 scenario such as that which was previously presented in this chapter. The pollutant reductions in the Stage 1 scenario are targeted only at the controllable, anthropogenic sources identified in the TMDL. During the implementation of the Stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in 6.2 above. VADEQ will re-assess water quality in the stream during and subsequent to the implementation of the Stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, and no additional cost-effective and reasonable BMPs can be identified, a UAA may be initiated with the goal of re-designating the stream for a more appropriate use.

7. PUBLIC PARTICIPATION

The development of the Upper North Fork Holston River TMDL greatly benefited from public involvement. Table 7.1 details the public participation throughout the project. The first Technical Advisory Committee (TAC) meeting was held on July 14, 2005 at the Friends Community Church in Saltville, Virginia. In attendance were 12 people, including representatives from VADEQ, VADCR, Holston River SWCD, Evergreen SWCD, Virginia Department of Forestry, Virginia Department of Game and Inland Fisheries, New River Highlands RC & D, the U. S. Army Corps of Engineers, the Town of Saltville, and MapTech, Inc. At this meeting, the RBP II and VASCI scores were discussed, and chloride was identified as the most probable stressor.

Table 7.1 Public participation during TMDL development for the Upper North Fork Holston River watershed.

Date	Location	Attendance[1]	Type	Format
7/14/05	Friends Community Church Saltville, VA	12	1st TAC	Open to government agents
7/14/05	Friends Community Church Saltville, VA	19	1st public	Open to public at large
			Final public	Open to public at large

[1]The number of attendants is estimated from sign up sheets provided at each meeting. These numbers are known to underestimate the actual attendance.

The first public meeting was also held on July 14, 2005 at the Friends Community Church in Saltville. The meeting was attended by 19 people, including nine local stakeholders, eight agency representatives, and two consultants. The agencies represented at this meeting included: VADEQ, VADCR, Holston River SWCD, New River Highlands Resource Conservation and Development Council (RC & D), and the U. S. Army Corps of Engineers. The meeting was publicized via mail and email, as well as in local newspapers and the Virginia Register. In addition, several signs were placed on the road right-of-way along Holston River and in Saltville.

Public participation during the implementation plan development process will include the formation of a stakeholders' committee as well as open public meetings. Public participation is critical to promote reasonable assurances that the implementation activities will occur. A stakeholders' committee will have the express purpose of formulating the TMDL implementation plan. The major stakeholders were identified during the development of this TMDL. The committee will consist of, but not be limited to, representatives from VADEQ, VADCR, and local governments. This committee will have the responsibility for identifying corrective actions that are founded in practicality, establishing a time line to ensure expeditious implementation, and setting measurable goals and milestones for attaining water quality standards.

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GLOSSARY

Note: All entries in italics are taken from USEPA (1998).

303(d). A section of the Clean Water Act of 1972 requiring states to identify and list water bodies that do not meet the states' water quality standards.

Allocations. *That portion of a receiving water's loading capacity attributed to one of its existing or future pollution sources (nonpoint or point) or to natural background sources. (A wasteload allocation [WLA] is that portion of the loading capacity allocated to an existing or future point source, and a load allocation [LA] is that portion allocated to an existing or future nonpoint source or to natural background levels. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading.)*

***Ambient water quality*. *Natural concentration of water quality constituents prior to mixing of either point or nonpoint source load of contaminants. Reference ambient concentration is used to indicate the concentration of a chemical that will not cause adverse impact on human health.*

Anthropogenic. *Pertains to the [environmental] influence of human activities.*

***Antidegradation Policies*. *Policies that are part of each states water quality standards. These policies are designed to protect water quality and provide a method of assessing activities that might affect the integrity of waterbodies.*

Aquatic ecosystem. *Complex of biotic and abiotic components of natural waters. The aquatic ecosystem is an ecological unit that includes the physical characteristics (such as flow or velocity and depth), the biological community of the water column and benthos, and the chemical characteristics such as dissolved solids, dissolved oxygen, and nutrients. Both living and nonliving components of the aquatic ecosystem interact and influence the properties and status of each component.*

***Assimilative capacity*. *The amount of contaminant load that can be discharged to a specific waterbody without exceeding water quality standards or criteria. Assimilative capacity is used to define the ability of a waterbody to naturally absorb and use a discharged substance without impairing water quality or harming aquatic life.*

Background levels. *Levels representing the chemical, physical, and biological conditions that would result from natural geomorphological processes such as weathering or dissolution.*

Benthic. *Refers to material, especially sediment, at the bottom of an aquatic ecosystem. It can be used to describe the organisms that live on, or in, the bottom of a waterbody.*

Benthic organisms. *Organisms living in, or on, bottom substrates in aquatic ecosystems.*

Best management practices (BMPs). *Methods, measures, or practices determined to be reasonable and cost-effective means for a landowner to meet certain, generally nonpoint source, pollution control needs. BMPs include structural and nonstructural controls and operation and maintenance procedures.*

Bioassessment. Evaluation of the condition of an ecosystem that uses biological surveys and other direct measurements of the resident biota. **(2)**

Biochemical Oxygen Demand (BOD). Represents the amount of oxygen consumed by bacteria as they break down organic matter in the water.

Biological Integrity. A water body's ability to support and maintain a balanced, integrated adaptive assemblage of organisms with species composition, diversity, and functional organization comparable to that of similar natural, or non-impacted habitat.

Biometric. (Biological Metric) The study of biological phenomena by measurements and statistics.

Box and whisker plot. A graphical representation of the mean, lower quartile, upper quartile, upper limit, lower limit, and outliers of a data set.

Calibration. *The process of adjusting model parameters within physically defensible ranges until the resulting predictions give a best possible good fit to observed data.*

Cause. 1. That which produces an effect (a general definition).
2. A stressor or set of stressors that occur at an intensity, duration and frequency of exposure that results in a change in the ecological condition (a SI-specific definition).[2]

Channel. *A natural stream that conveys water; a ditch or channel excavated for the flow of water.*

Chloride. *An atom of chlorine in solution; an ion bearing a single negative charge.*

Clean Water Act (CWA). *The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. The Clean Water Act (CWA) contains a number of provisions to restore and maintain the quality of the nation's water resources. One of these provisions is Section 303(d), which establishes the TMDL program.*

Concentration. *Amount of a substance or material in a given unit volume of solution; usually measured in milligrams per liter (mg/L) or parts per million (ppm).*

Concentration-based limit. *A limit based on the relative strength of a pollutant in a waste stream, usually expressed in milligrams per liter (mg/L).*

Concentration-response model. A quantitative (usually statistical) model of the relationship between the concentration of a chemical to which a population or community of organisms is exposed and the frequency or magnitude of a biological response. (2)

Conductivity. An indirect measure of the presence of dissolved substances within water.

Confluence. The point at which a river and its tributary flow together.

Contamination. *The act of polluting or making impure; any indication of chemical, sediment, or biological impurities.*

Continuous discharge. *A discharge that occurs without interruption throughout the operating hours of a facility, except for infrequent shutdowns for maintenance, process changes, or other similar activities.*

Conventional pollutants. *As specified under the Clean Water Act, conventional contaminants include suspended solids, coliform bacteria, high biochemical oxygen demand, pH, and oil and grease.*

Conveyance. A measure of the of the water carrying capacity of a channel section. It is directly proportional to the discharge in the channel section.

Cost-share program. *A program that allocates project funds to pay a percentage of the cost of constructing or implementing a best management practice. The remainder of the costs is paid by the producer(s).*

Cross-sectional area. *Wet area of a waterbody normal to the longitudinal component of the flow.*

Critical condition. *The critical condition can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence.*

Decay. *The gradual decrease in the amount of a given substance in a given system due to various sink processes including chemical and biological transformation, dissipation to other environmental media, or deposition into storage areas.*

Decomposition. *Metabolic breakdown of organic materials; the formation of by-products of decomposition releases energy and simple organic and inorganic compounds. See also* ***Respiration.***

Designated uses. *Those uses specified in water quality standards for each waterbody or segment whether or not they are being attained.*

Dilution. *The addition of some quantity of less-concentrated liquid (water) that results in a decrease in the original concentration.*

Direct runoff. *Water that flows over the ground surface or through the ground directly into streams, rivers, and lakes.*

Discharge. *Flow of surface water in a stream or canal, or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.*

Discharge Monitoring Report (DMR). *Report of effluent characteristics submitted by a municipal or industrial facility that has been granted an NPDES discharge permit.*

Discharge permits (under NPDES)*. A permit issued by the EPA or a state regulatory agency that sets specific limits on the type and amount of pollutants that a municipality or industry can discharge to a receiving water; it also includes a compliance schedule for achieving those limits. The permit process was established under the National Pollutant Discharge Elimination System, under provisions of the Federal Clean Water Act.*

Dispersion*. The spreading of chemical or biological constituents, including pollutants, in various directions at varying velocities depending on the differential in-stream flow characteristics.*

Dissolved Oxygen (DO). The amount of oxygen in water. DO is a measure of the amount of oxygen available for biochemical activity in a waterbody.

Diurnal. *Actions or processes that have a period or a cycle of approximately one tidal-day or are completed within a 24-hour period and that recur every 24 hours. Also, the occurrence of an activity/process during the day rather than the night.*

DNA. Deoxyribonucleic acid. The genetic material of cells and some viruses.

Domestic wastewater. *Also called sanitary wastewater, consists of wastewater discharged from residences and from commercial, institutional, and similar facilities.*

Drainage basin. *A part of a land area enclosed by a topographic divide from which direct surface runoff from precipitation normally drains by gravity into a receiving water. Also referred to as a watershed, river basin, or hydrologic unit.*

Dynamic model. *A mathematical formulation describing and simulating the physical behavior of a system or a process and its temporal variability.*

Dynamic simulation. *Modeling of the behavior of physical, chemical, and/or biological phenomena and their variations over time.*

Ecoregion. A region defined in part by its shared characteristics. These include meteorological factors, elevation, plant and animal speciation, landscape position, and soils.

Ecosystem. *An interactive system that includes the organisms of a natural community association together with their abiotic physical, chemical, and geochemical environment.*

Effluent. *Municipal sewage or industrial liquid waste (untreated, partially treated, or completely treated) that flows out of a treatment plant, septic system, pipe, etc.*

Effluent guidelines. *The national effluent guidelines and standards specify the achievable effluent pollutant reduction that is attainable based upon the performance of treatment technologies employed within an industrial category. The National Effluent Guidelines Program was established with a phased approach whereby industry would first be required to meet interim limitations based on best practicable control technology currently available for existing sources (BPT). The second level of effluent limitations to be attained by industry was referred to as best available technology economically achievable (BAT), which was established primarily for the control of toxic pollutants.*

Effluent limitation. *Restrictions established by a state or EPA on quantities, rates, and concentrations in pollutant discharges.*

Endpoint. *An endpoint (or indicator/target) is a characteristic of an ecosystem that may be affected by exposure to a stressor. Assessment endpoints and measurement endpoints are two distinct types of endpoints commonly used by resource managers. An assessment endpoint is the formal expression of a valued environmental characteristic and should have societal relevance (an indicator). A measurement endpoint is the expression of an observed or measured response to a stress or disturbance. It is a measurable environmental characteristic that is related to the valued environmental characteristic chosen as the assessment endpoint. The numeric criteria that are part of traditional water quality standards are good examples of measurement endpoints (targets).*

Enhancement. *In the context of restoration ecology, any improvement of a structural or functional attribute.*

Erosion. The detachment and transport of soil particles by water and wind. Sediment resulting from soil erosion represents the single largest source of nonpoint pollution in the United States.

Eutrophication. The process of enrichment of water bodies by nutrients. Waters receiving excessive nutrients may become eutrophic, are often undersirable for recreation, and may not support normal fish populations.

Evapotranspiration. The combined effects of evaporation and transpiration on the water balance. Evaporation is water loss into the atmosphere from soil and water surfaces. Transpiration is water loss into the atmosphere as part of the life cycle of plants.

Fate of pollutants*. Physical, chemical, and biological transformation in the nature and changes of the amount of a pollutant in an environmental system. Transformation processes are pollutant-specific. Because they have comparable kinetics, different formulations for each pollutant are not required.*

Feedlot. *A confined area for the controlled feeding of animals. Tends to concentrate large amounts of animal waste that cannot be absorbed by the soil and, hence, may be carried to nearby streams or lakes by rainfall runoff.*

Flux. *Movement and transport of mass of any water quality constituent over a given period of time. Units of mass flux are mass per unit time.*

General Standard. A narrative standard that ensures the general health of state waters. All state waters, including wetlands, shall be free from substances attributable to sewage, industrial waste, or other waste in concentrations, amounts, or combinations which contravene established standards or interfere directly or indirectly with designated uses of such water or which are inimical or harmful to human, animal, plant, or aquatic life (9VAC25-260-20). (4)

GIS. Geographic Information System. A system of hardware, software, data, people, organizations and institutional arrangements for collecting, storing, analyzing and disseminating information about areas of the earth. (Dueker and Kjerne, 1989)

Ground water. *The supply of fresh water found beneath the earths surface, usually in aquifers, which supply wells and springs. Because ground water is a major source of drinking water, there is growing concern over contamination from leaching agricultural or industrial pollutants and leaking underground storage tanks.*

HSPF. Hydrological Simulation Program – Fortran. A computer simulation tool used to mathematically model nonpoint source pollution sources and movement of pollutants in a watershed.

Hydrograph*. A graph showing variation of stage (depth) or discharge in a stream over a period of time.*

Hydrologic cycle*. The circuit of water movement from the atmosphere to the earth and its return to the atmosphere through various stages or processes, such as precipitation, interception, runoff, infiltration, storage, evaporation, and transpiration.*

Hydrology*. The study of the distribution, properties, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.*

Impairment. A detrimental effect on the biological integrity of a water body that prevents attainment of the designated use.

IMPLND. An impervious land segment in HSPF. It is used to model land covered by impervious materials, such as pavement.

Indicator. *A measurable quantity that can be used to evaluate the relationship between pollutant sources and their impact on water quality.*

Indirect causation. The induction of effects through a series of cause-effect relationships, so that the impaired resource may not even be exposed to the initial cause.

Indirect effects. Changes in a resource that are due to a series of cause-effect relationships rather than to direct exposure to a contaminant or other stressor.

***Infiltration capacity**. The capacity of a soil to allow water to infiltrate into or through it during a storm.*

***In situ.** In place; in situ measurements consist of measurements of components or processes in a full-scale system or a field, rather than in a laboratory.*

Interflow. Runoff that travels just below the surface of the soil.

***Leachate.** Water that collects contaminants as it trickles through wastes, pesticides, or fertilizers. Leaching can occur in farming areas, feedlots, and landfills and can result in hazardous substances entering surface water, ground water, or soil.*

Limits (upper and lower). The lower limit equals the lower quartile – 1.5x(upper quartile – lower quartile), and the upper limit equals the upper quartile + 1.5x(upper quartile – lower quartile). Values outside these limits are referred to as outliers.

***Loading, Load, Loading rate**. The total amount of material (pollutants) entering the system from one or multiple sources; measured as a rate in weight per unit time.*

***Load allocation (LA).** The portion of a receiving waters loading capacity attributed either to one of its existing or future nonpoint sources of pollution or to natural background sources. Load allocations are best estimates of the loading, which can range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading. Wherever possible, natural and nonpoint source loads should be distinguished (40 CFR 130.2(g)).*

***Loading capacity (LC).** The greatest amount of loading a water can receive without violating water quality standards.*

***Margin of safety (MOS).** A required component of the TMDL that accounts for the uncertainty about the relationship between the pollutant loads and the quality of the receiving waterbody (CWA Section 303(d)(1)(C)). The MOS is normally incorporated into the conservative assumptions used to develop TMDLs (generally within the calculations or models) and approved by the EPA either individually or in state/EPA agreements. If the MOS needs to be larger than that which is allowed through the conservative assumptions, additional MOS can be added as a separate component of the TMDL (in this case, quantitatively, a TMDL = LC = WLA + LA + MOS).*

***Mass balance.** An equation that accounts for the flux of mass going into a defined area and the flux of mass leaving the defined area. The flux in must equal the flux out.*

***Mass loading.** The quantity of a pollutant transported to a waterbody.*

Mean. The sum of the values in a data set divided by the number of values in the data set.

Metrics. Indices or parameters used to measure some aspect or characteristic of a water body's biological integrity. The metric changes in some predictable way with changes in water quality or habitat condition.

MGD. Million gallons per day. A unit of water flow, whether discharge or withdraw.

Mitigation. *Actions taken to avoid, reduce, or compensate for the effects of environmental damage. Among the broad spectrum of possible actions are those that restore, enhance, create, or replace damaged ecosystems.*

Model. Mathematical representation of hydrologic and water quality processes. Effects of land use, slope, soil characteristics, and management practices are included.

Monitoring. *Periodic or continuous surveillance or testing to determine the level of compliance with statutory requirements and/or pollutant levels in various media or in humans, plants, and animals.*

Mood's Median Test. A nonparametric (distribution-free) test used to test the equality of medians from two or more populations.

Narrative criteria*. Nonquantitative guidelines that describe the desired water quality goals.*

National Pollutant Discharge Elimination System (NPDES). *The national program for issuing, modifying, revoking and re-issuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements, under sections 307, 402, 318, and 405 of the Clean Water Act.*

Natural waters. *Flowing water within a physical system that has developed without human intervention, in which natural processes continue to take place.*

Nitrogen. An essential nutrient to the growth of organisms. Excessive amounts of nitrogen in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Nonpoint source. *Pollution that originates from multiple sources over a relatively large area. Nonpoint sources can be divided into source activities related to either land or water use including failing septic tanks, improper animal-keeping practices, forest practices, and urban and rural runoff.*

Numeric targets*. A measurable value determined for the pollutant of concern, which, if achieved, is expected to result in the attainment of water quality standards in the listed waterbody.*

Numerical model*.* Model that approximates a solution of governing partial differential equations, which describe a natural process. The approximation uses a numerical discretization of the space and time components of the system or process.

Nutrient. An element or compound essential to life, including carbon, oxygen, nitrogen, phosphorus, and many others: as a pollutant, any element or compound, such as phosphorus or nitrogen, that in excessive amounts contributes to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Organic matter. *The organic fraction that includes plant and animal residue at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil population. Commonly determined as the amount of organic material contained in a soil or water sample.*

Parameter. A numerical descriptive measure of a population. Since it is based on the observations of the population, its value is almost always unknown.

Peak runoff*. The highest value of the stage or discharge attained by a flood or storm event; also referred to as flood peak or peak discharge.*

PERLND. A pervious land segment in HSPF. It is used to model a particular land use segment within a subwatershed (e.g. pasture, urban land, or crop land).

Permit. *An authorization, license, or equivalent control document issued by the EPA or an approved federal, state, or local agency to implement the requirements of an environmental regulation; e.g., a permit to operate a wastewater treatment plant or to operate a facility that may generate harmful emissions.*

Permit Compliance System (PCS). *Computerized management information system that contains data on NPDES permit-holding facilities. PCS keeps extensive records on more than 65,000 active water-discharge permits on sites located throughout the nation. PCS tracks permit, compliance, and enforcement status of NPDES facilities.*

Phased/staged approach. *Under the phased approach to TMDL development, load allocations and wasteload allocations are calculated using the best available data and information recognizing the need for additional monitoring data to accurately characterize sources and loadings. The phased approach is typically employed when nonpoint sources dominate. It provides for the implementation of load reduction strategies while collecting additional data.*

Phosphorus. An essential nutrient to the growth of organisms. Excessive amounts of phosphorus in water can contribute to abnormally high growth of algae, reducing light and oxygen in aquatic ecosystems.

Point source. *Pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants or industrial waste treatment facilities. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river.*

Pollutant. *Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or* *discarded equipment, rock, sand, cellar dirt, and industrial, municipal, and agricultural waste discharged into water. (CWA section 502(6)).*

Pollution. *Generally, the presence of matter or energy whose nature, location, or quantity produces undesired environmental effects. Under the Clean Water Act, for example, the term is defined as the man-made or man-induced alteration of the physical, biological, chemical, and radiological integrity of water.*

Postaudit. *A subsequent examination and verification of a model's predictive performance following implementation of an environmental control program.*

Privately owned treatment works*. Any device or system that is (a) used to treat wastes from any facility whose operator is not the operator of the treatment works and (b) not a publicly owned treatment works.*

Public comment period*. The time allowed for the public to express its views and concerns regarding action by the EPA or states (e.g., a* Federal Register *notice of a proposed rule-making, a public notice of a draft permit, or a Notice of Intent to Deny).*

Publicly owned treatment works (POTW). *Any device or system used in the treatment (including recycling and reclamation) of municipal sewage or industrial wastes of a liquid nature that is owned by a state or municipality. This definition includes sewers, pipes, or other conveyances only if they convey wastewater to a POTW providing treatment.*

Quartile. The 25^{th}, 50^{th}, and 75^{th} percentiles of a data set. A percentile (p) of a data set ordered by magnitude is the value that has at most p% of the measurements in the data set below it, and (100-p)% above it. The 50^{th} quartile is also known as the median. The 25^{th} and 75^{th} quartiles are referred to as the lower and upper quartiles, respectively.

Rapid Bioassessment Protocol II (RBP II). A suite of measurements based on a quantitative assessment of benthic macroinvertebrates and a qualitative assessment of their habitat. RBP II scores are compared to a reference condition or conditions to determine to what degree a water body may be biologically impaired.

Reach. Segment of a stream or river.

Receiving waters. *Creeks, streams, rivers, lakes, estuaries, ground-water formations, or other bodies of water into which surface water and/or treated or untreated waste are discharged, either naturally or in man-made systems.*

Reference Conditions. The chemical, physical, or biological quality or condition exhibited at either a single site or an aggregation of sites that are representative of non-impaired conditions for a watershed of a certain size, land use distribution, and other related characteristics. Reference conditions are used to describe reference sites.

Reserve capacity*. Pollutant loading rate set aside in determining stream waste load allocation, accounting for uncertainty and future growth.*

Residence time. *Length of time that a pollutant remains within a section of a stream or river. The residence time is determined by the streamflow and the volume of the river reach or the average stream velocity and the length of the river reach.*

Restoration*. Return of an ecosystem to a close approximation of its presumed condition prior to disturbance.*

Riparian areas. *Areas bordering streams, lakes, rivers, and other watercourses. These areas have high water tables and support plants that require saturated soils during all or part of the year. Riparian areas include both wetland and upland zones.*

Riparian zone*. The border or banks of a stream. Although this term is sometimes used interchangeably with floodplain, the riparian zone is generally regarded as relatively narrow compared to a floodplain. The duration of flooding is generally much shorter, and the timing less predictable, in a riparian zone than in a river floodplain.*

Roughness coefficient*. A factor in velocity and discharge formulas representing the effects of channel roughness on energy losses in flowing water. Manning's "n" is a commonly used roughness coefficient.*

Runoff. *That part of precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water. It can carry pollutants from the air and land into receiving waters.*

Seasonal Kendall test. A statistical tool used to test for trends in data, which is unaffected by seasonal cycles. (Gilbert, 1987)

Sediment. In the context of water quality, soil particles, sand, and minerals dislodged from the land and deposited into aquate systems as a result of erosion.

Septic system*. An on-site system designed to treat and dispose of domestic sewage. A typical septic system consists of a tank that receives waste from a residence or business and a drain field or subsurface absorption system consisting of a series of percolation lines for the disposal of the liquid effluent. Solids (sludge) that remain after decomposition by bacteria in the tank must be pumped out periodically.*

Sewer. *A channel or conduit that carries wastewater and storm water runoff from the source to a treatment plant or receiving stream. Sanitary sewers carry household, industrial, and commercial waste. Storm sewers carry runoff from rain or snow. Combined sewers handle both.*

Simulation*. The use of mathematical models to approximate the observed behavior of a natural water system in response to a specific known set of input and forcing conditions. Models that have been validated, or verified, are then used to predict the response of a natural water system to changes in the input or forcing conditions.*

Slope. *The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25 or 1 on 25, indicating one unit vertical rise in 25 units of horizontal distance, or in a decimal fraction (0.04), degrees (2 degrees 18 minutes), or percent (4 percent).*

Source. An origination point, area, or entity that releases or emits a stressor. A source can alter the normal intensity, frequency, or duration of a natural attribute, whereby the attribute then becomes a stressor.

Spatial segmentation. *A numerical discretization of the spatial component of a system into one or more dimensions; forms the basis for application of numerical simulation models.*

Staged Implementation. A process that allows for the evaluation of the adequacy of the TMDL in achieving the water quality standard. As stream monitoring continues to occur, staged or phased implementation allows for water quality improvements to be recorded as they are being achieved. It also provides a measure of quality control, and it helps to ensure that the most cost-effective practices are implemented first.

Stakeholder. Any person with a vested interest in the TMDL development.

Standard. In reference to water quality (e.g. 200 cfu/100 mL geometric mean limit).

Standard deviation. A measure of the variability of a data set. The positive square root of the variance of a set of measurements.

Standard error. The standard deviation of a distribution of a sample statistic, esp. when the mean is used as the statistic.

Statistical significance. An indication that the differences being observed are not due to random error. The p-value indicates the probability that the differences are due to random error (i.e. a low p-value indicates statistical significance).

Steady-state model. *Mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving water quality concentrations. Model variables are treated as not changing with respect to time.*

Storm runoff. *Storm water runoff, snowmelt runoff, and surface runoff and drainage; rainfall that does not evaporate or infiltrate the ground because of impervious land surfaces or a soil infiltration rate lower than rainfall intensity, but instead flows onto adjacent land or into waterbodies or is routed into a drain or sewer system.*

Streamflow. *Discharge that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream course. The term "streamflow" is more general than "runoff" since streamflow may be applied to discharge whether or not it is affected by diversion or regulation.*

Stream Reach. A straight portion of a stream.

Stream restoration. *Various techniques used to replicate the hydrological, morphological, and ecological features that have been lost in a stream because of urbanization, farming, or other disturbance.*

Stressor. Any physical, chemical, or biological entity that can induce an adverse response. [2]

Surface area. *The area of the surface of a waterbody; best measured by planimetry or the use of a geographic information system.*

Surface runoff. *Precipitation, snowmelt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants.*

Surface water. *All water naturally open to the atmosphere (rivers, lakes, reservoirs, ponds, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors directly influenced by surface water.*

Suspended Solids. Usually fine sediments and organic matter. Suspended solids limit sunlight penetration into the water, inhibit oxygen uptake by fish, and alter aquatic habitat.

Technology-based standards. *Effluent limitations applicable to direct and indirect sources that are developed on a category-by-category basis using statutory factors, not including water quality effects.*

Timestep. An increment of time in modeling terms. The smallest unit of time used in a mathematical simulation model (e.g. 15-minutes, 1-hour, 1-day).

Topography. *The physical features of a geographic surface area including relative elevations and the positions of natural and man-made features.*

Total Dissolved Solids (TDS). A measure of the concentration of dissolved inorganic chemicals in water.

Total Maximum Daily Load (TMDL). *The sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS). TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures that relate to a state's water quality standard.*

TMDL Implementation Plan. A document required by Virginia statute detailing the suite of pollution control measures needed to renediate an impaired stream segment. The plans are also required to include a schedule of actions, costs, and monitoring. Once implemented, the plan should result in the previously impaired water meeting water quality standards and achieving a "fully supporting" use support status.

Transport of pollutants (in water). *Transport of pollutants in water involves two main processes: (1) advection, resulting from the flow of water, and (2) dispersion, or transport due to turbulence in the water.*

Tributary. *A lower order-stream compared to a receiving waterbody. "Tributary to" indicates the largest stream into which the reported stream or tributary flows.*

Urban Runoff. Surface runoff originating from an urban drainage area including streets, parking lots, and rooftops.

Validation (of a model). *Process of determining how well the mathematical model's computer representation describes the actual behavior of the physical processes under investigation. A validated model will have also been tested to ascertain whether it accurately and correctly solves the equations being used to define the system simulation.*

Variance. A measure of the variability of a data set. The sum of the squared deviations (observation – mean) divided by (number of observations) – 1.

VADACS. Virginia Department of Agriculture and Consumer Services.

VADCR. Virginia Department of Conservation and Recreation.

VADEQ. Virginia Department of Environmental Quality.

VDH. Virginia Department of Health.

Wasteload allocation (WLA). *The portion of a receiving waters' loading capacity that is allocated to one of its existing or future point sources of pollution. WLAs constitute a type of water quality-based effluent limitation (40 CFR 130.2(h)).*

Wastewater. *Usually refers to effluent from a sewage treatment plant. See also Domestic wastewater.*

Wastewater treatment. *Chemical, biological, and mechanical procedures applied to an industrial or municipal discharge or to any other sources of contaminated water to remove, reduce, or neutralize contaminants.*

Water quality. *The biological, chemical, and physical conditions of a waterbody. It is a measure of a waterbody's ability to support beneficial uses.*

Water quality-based permit. *A permit with an effluent limit more stringent than one based on technology performance. Such limits might be necessary to protect the designated use of receiving waters (e.g., recreation, irrigation, industry, or water supply).*

Water quality criteria. *Levels of water quality expected to render a body of water suitable for its designated use, composed of numeric and narrative criteria. Numeric criteria are scientifically derived ambient concentrations developed by the EPA or states for various pollutants of concern to protect human health and aquatic life. Narrative criteria are statements that describe the desired water quality goal. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, fish production, or industrial processes.*

Water quality standard. *Law or regulation that consists of the beneficial designated use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an antidegradation statement.*

Watershed. *A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.*

WQIA. Water Quality Improvement Act.

APPENDIX A

Figure 1
Mercury in Northern Hogsucker
NFHRM 8

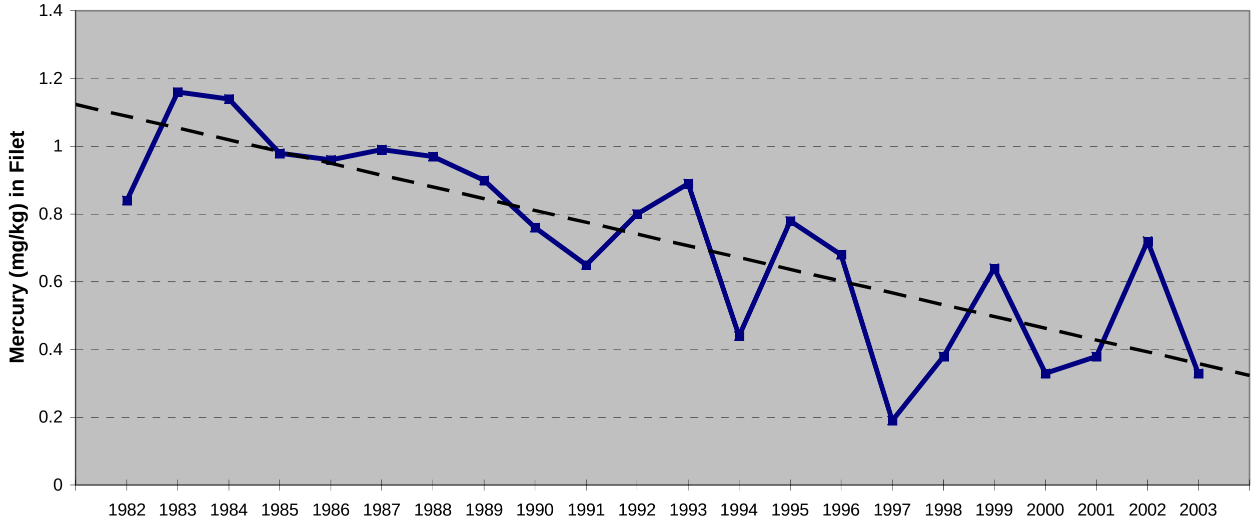

Figure 2
Mercury in Northern Hogsucker
NFHRM 69

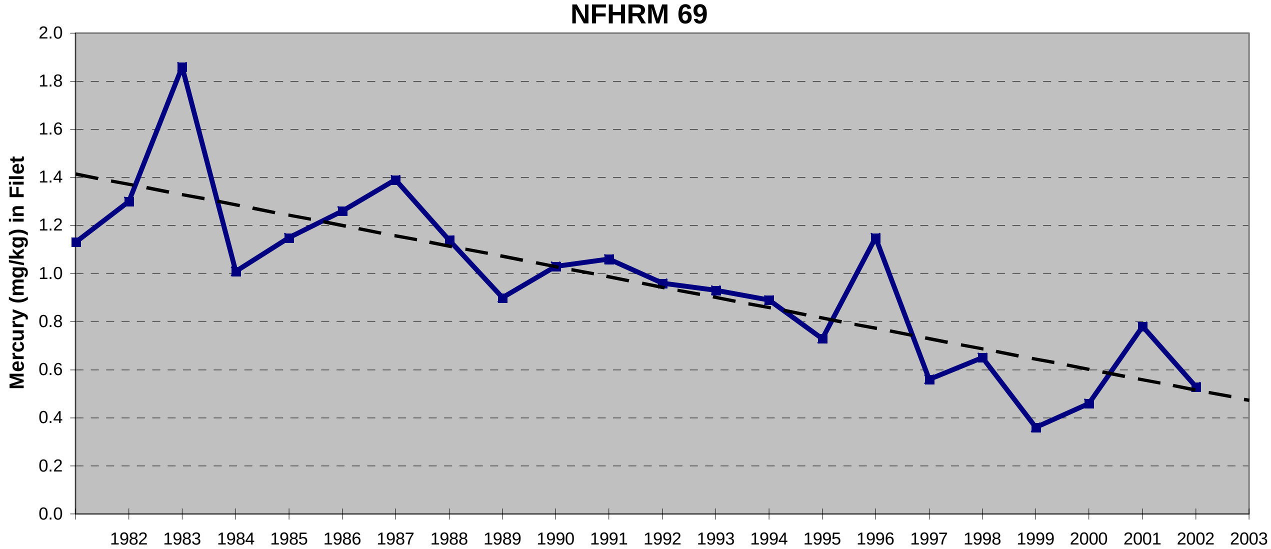

Figure 3
Mercury in Northern Hogsucker
NFHRM 77

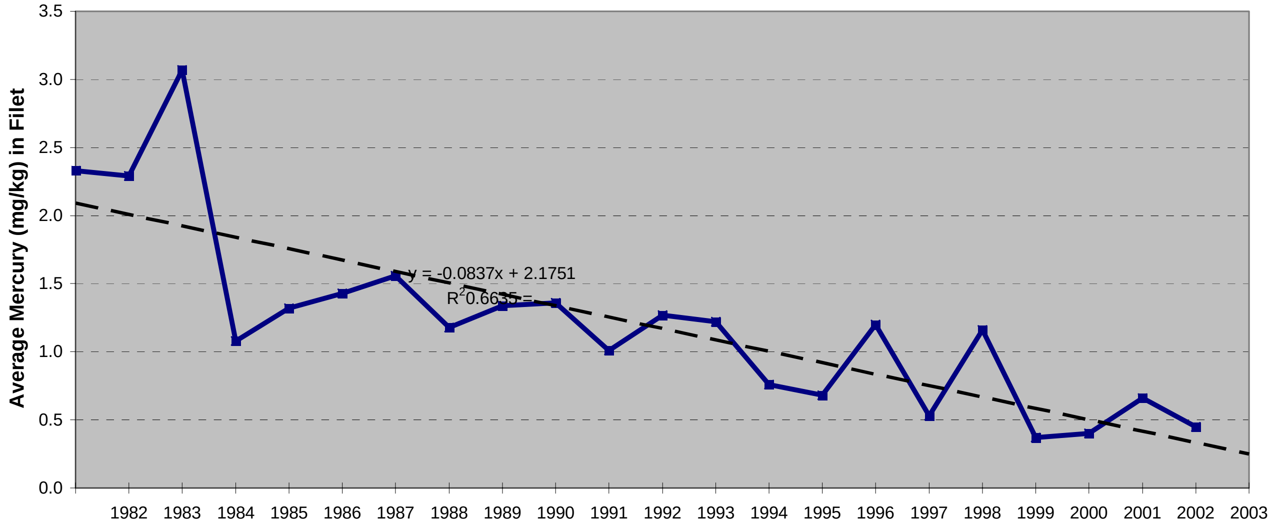

Figure 4
Changes in Mercury Concentrations in Fish Filets
Following Implementation of Remedial Actions
Northern Hogsucker

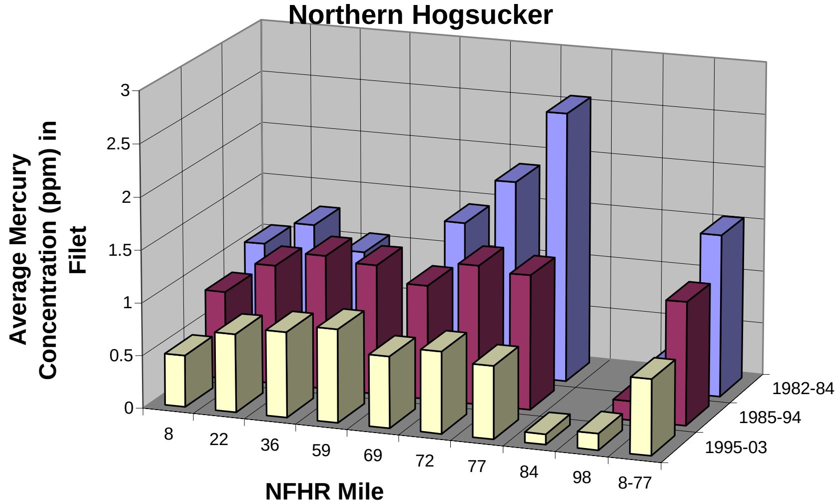

Figure 5
Mercury in Rock Bass
NFHRM 8

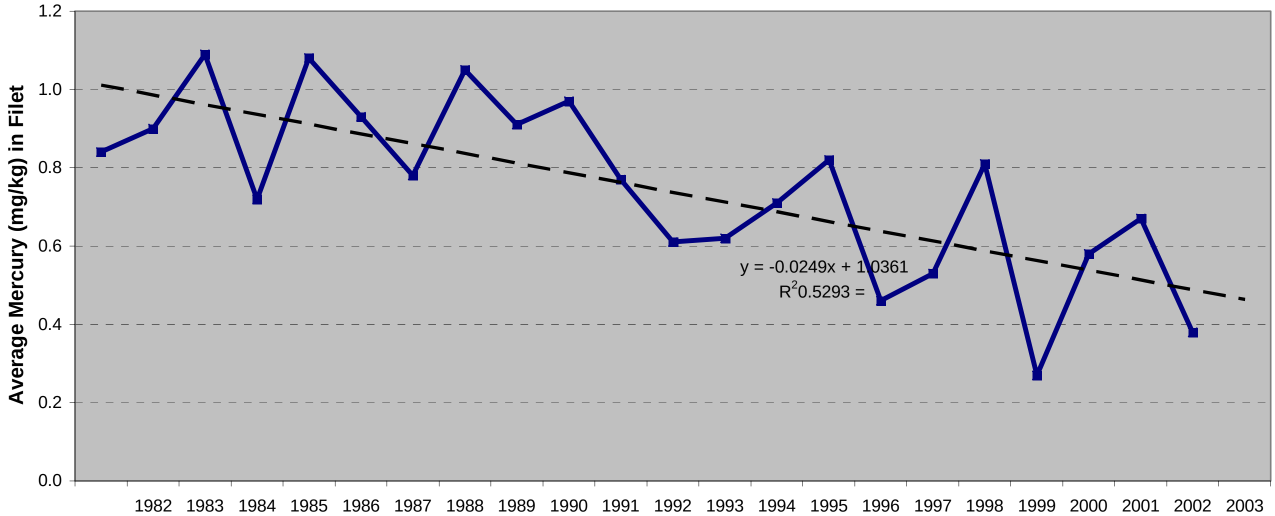

Figure 6
Mercury in Rock Bass
NFHRM 69

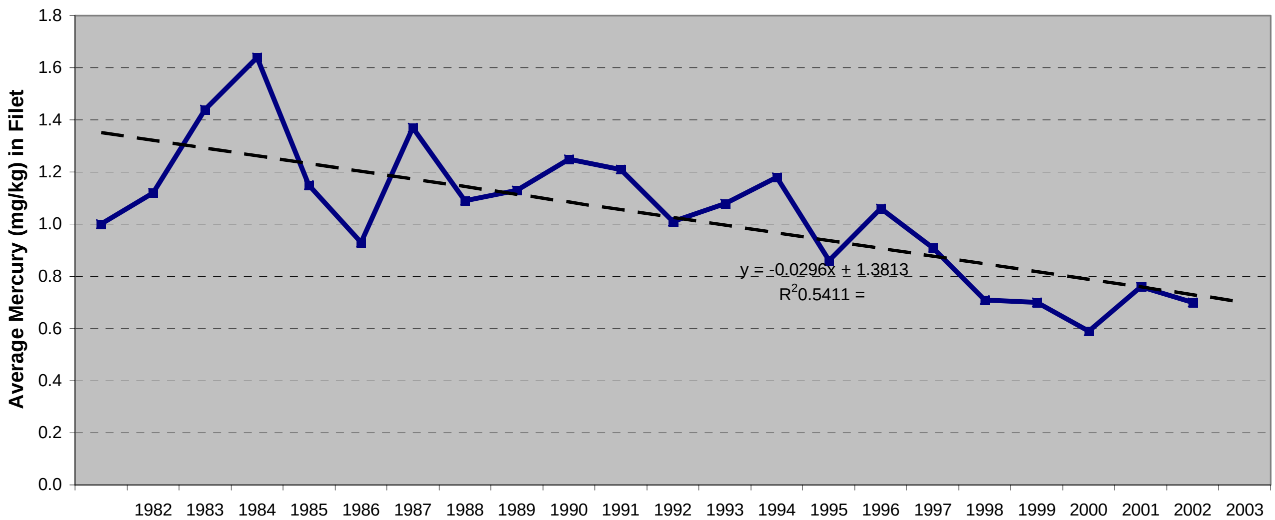

Figure 7
Mercury in Rock Bass
NFHRM 77

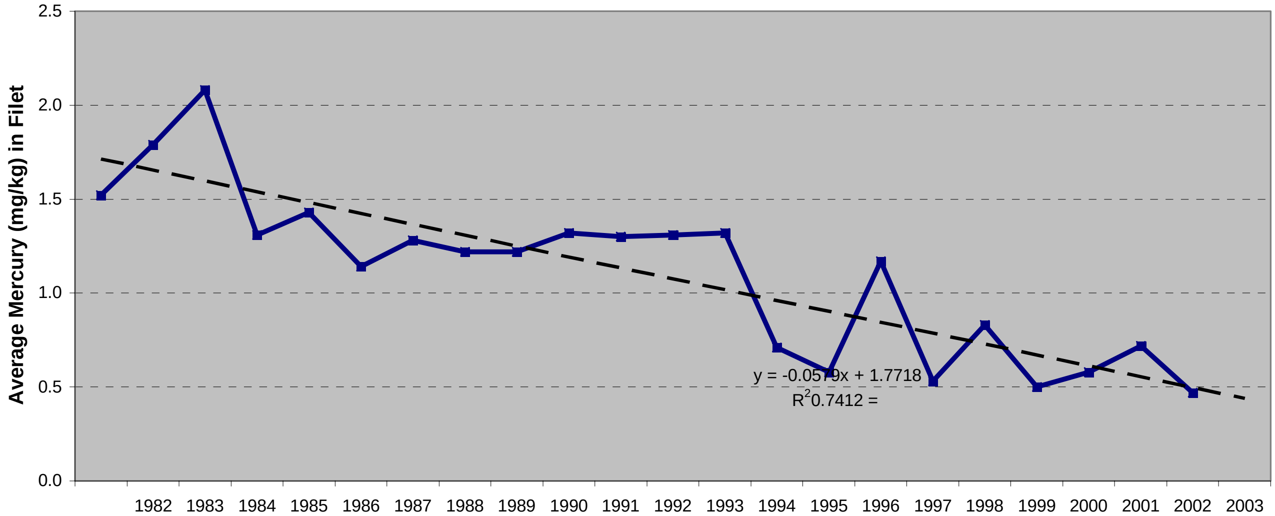

Figure 8
Changes in Mercury Concentrations in Fish Filets
Following Implementation of Remedial Actions
Rock Bass

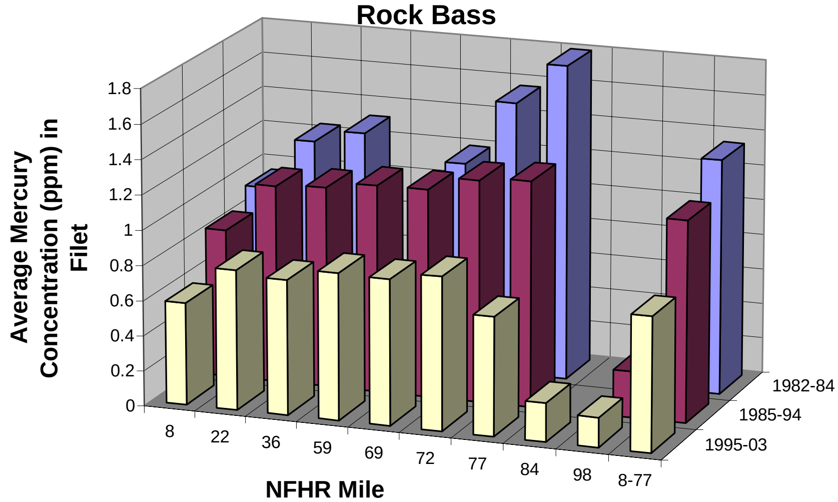

Figure 9
Mercury in Sunfish
NFHRM 8

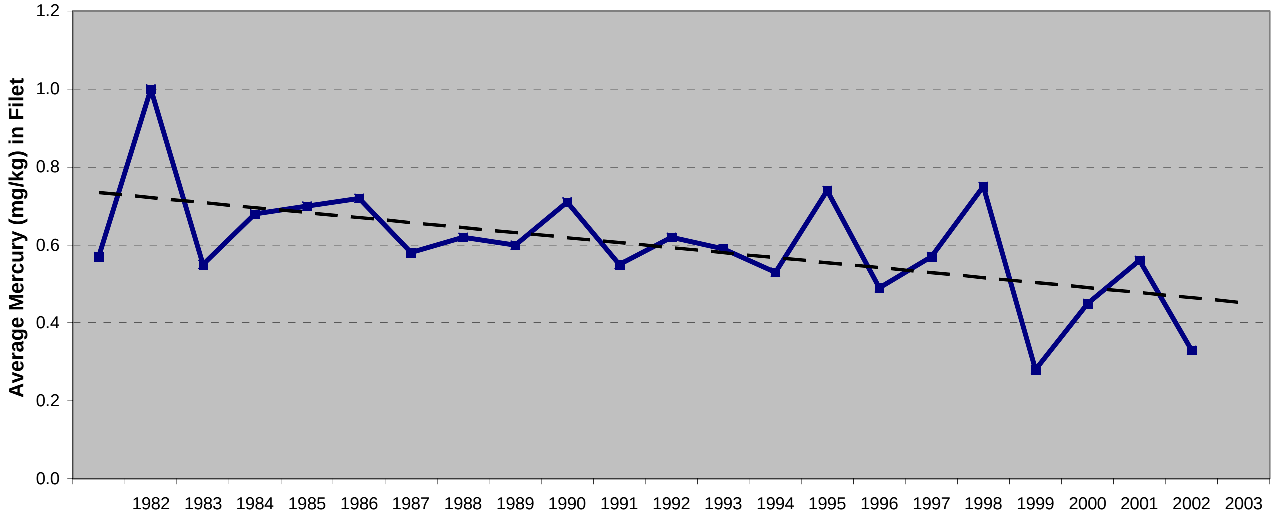

Figure 10
Mercury in Sunfish
NFHRM 69

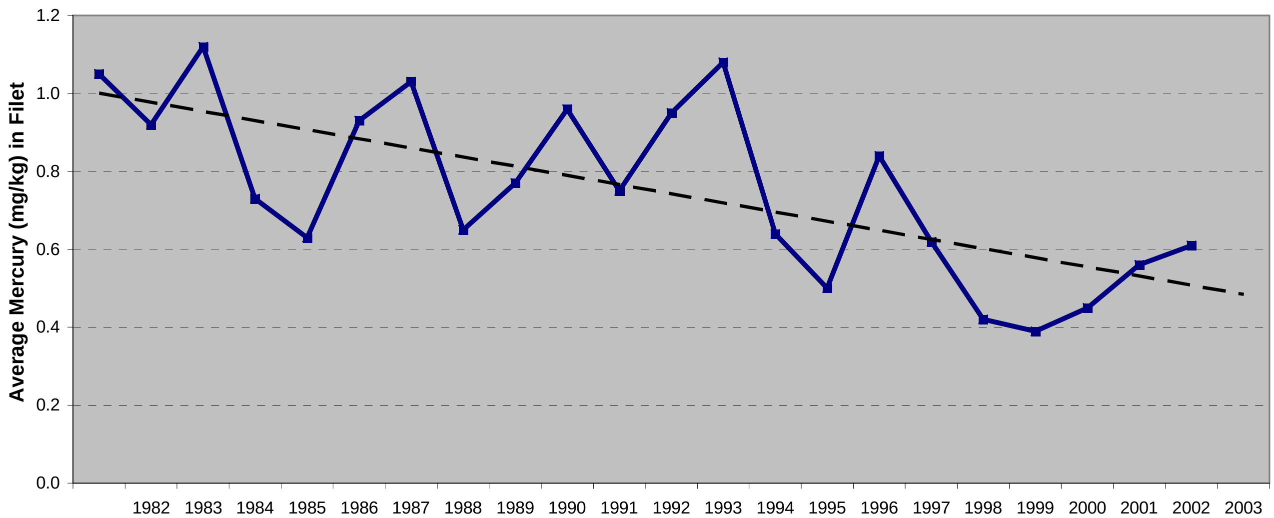

Figure 11
Mercury in Sunfish
NFHRM 77

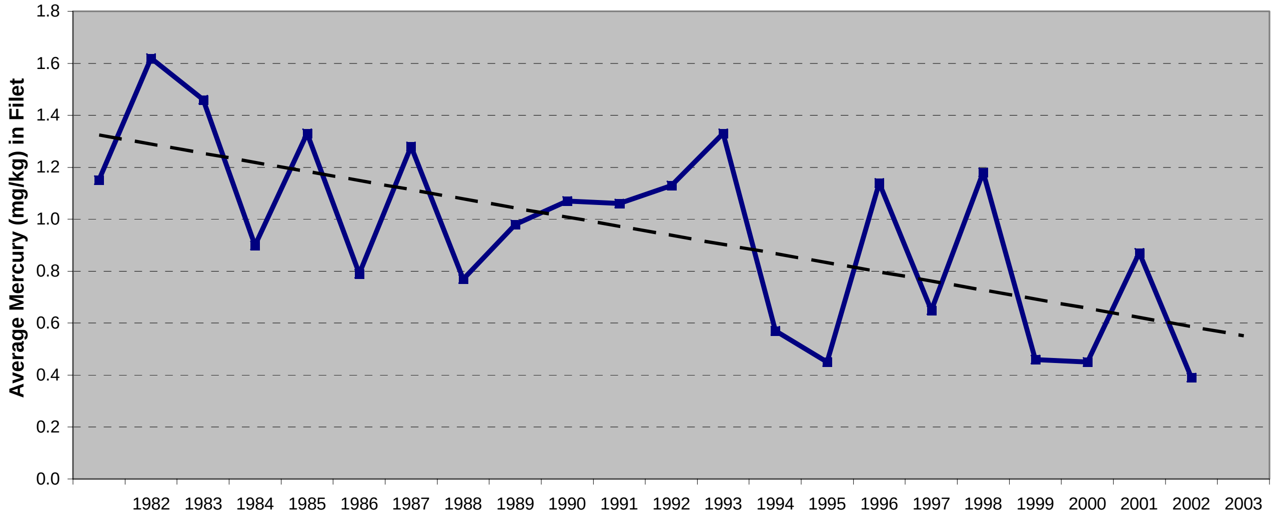

Figure 12
Changes in Mercury Concentrations in Fish Filets
Following Implementation of Remedial Actions
Sunfish

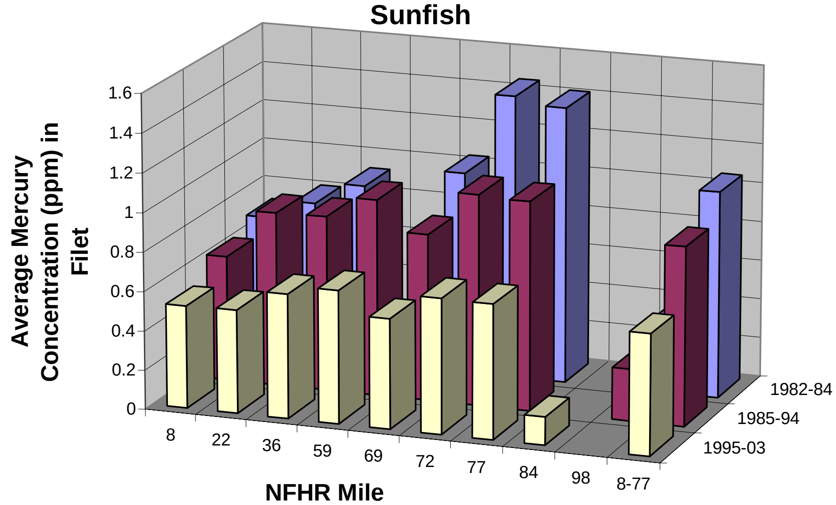

Figure 13
Average Mercury Concentrations in NFHR Fish From Downstream Collection Stations

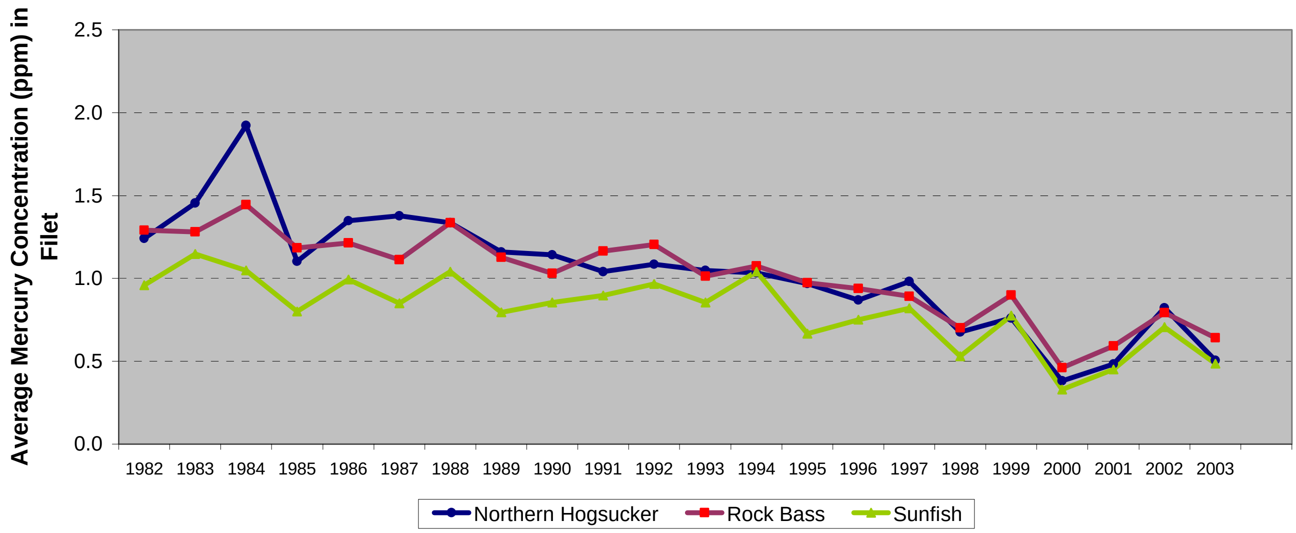

Figure 14
Average Mercury Concentrations in NFHR Sediment

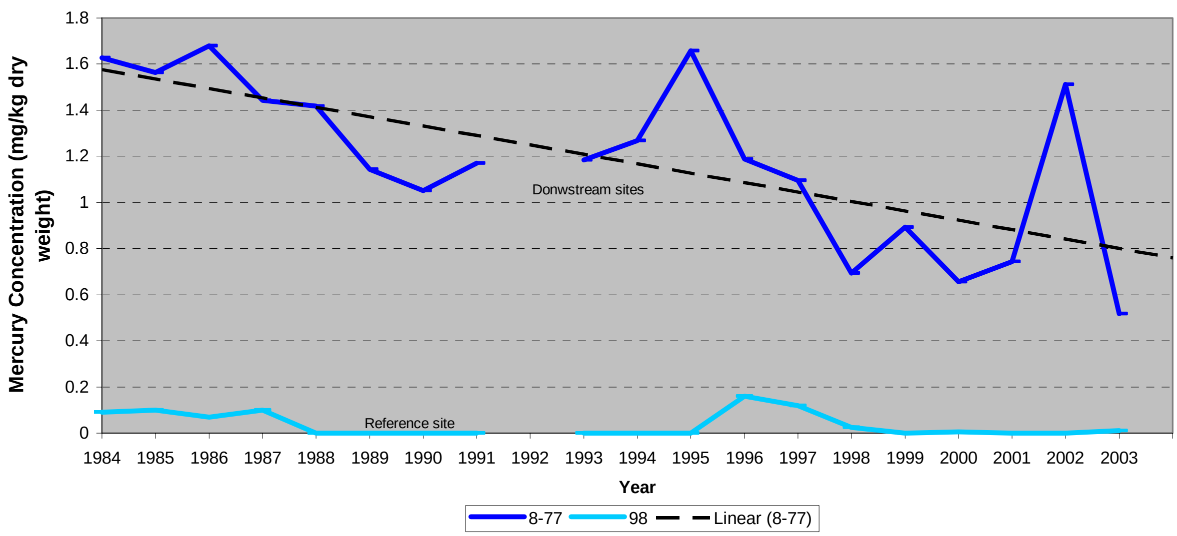

Figure 15
Changes in Mercury Concentrations in Sediments Following Implementation of Remedial Actions